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Formulation Requirements

Orbit Determination Executive (ODE)

Mission Planning and Analysis Division

September 1979

National Aeronautics and Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

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SHUTTLE PROGRAM

OPS MCC
GROUND NAVIGATION PROGRAM

LEVEL C
ORBIT DETERMINATION PROCESSING

FORMULATIONS REQUIREMENTS

ORBIT DETERMINATION EXECUTIVE (ODE)

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PREFACE

The Mathematical Physics Branch/Mission Planning and Analysis Division has the responsibility to provide the functional ground navigation software formulation requirements for the Mission Control Center (MCC) low-speed-processing phases during Operations Project Shuttle (OPS).

The ground navigation software formulation requirements are logically organized into volumes. This organization is presented in the accompanying table. The material in each volume presents the level C formulation requirements of the processors and modules required to process low-speed-tracking data and perform orbit determination computations. Each volume describes the formulation requirements of the identified processor or module specified in the OPS MCC Ground Navigation Program Level B Software document (ref. 1). The inputs and outputs required to accomplish the functions described are specified. Flow charts defining the sequence of mathematical operations and display and control processing required to satisfy the described functions are included in the document where appropriate.

Paragraphs relating to unique requirements for the automatic DC edit, which will not be included in the initial implementation, are enclosed in dashed lines.

OPS MCC GROUND NAVIGATION PROGRAM LEVEL C SOFTWARE REQUIREMENTS

ORBIT DETERMINATION PROCESSING FORMULATION DOCUMENT

Volume I	Introduction and Overview
Volume II	Low-Speed Input Processor (LSIP)
Volume III	Bias Correction Processor (BCP)
Volume IV	Data File Control Processor (DFCP)
Volume V	Orbit Determination Executive (ODE)
Volume VI	Convergence Processor (CP)
Volume VII	Differential Correction Module (DCM)
Volume VIII	Data Editing Processor (DEP)
Volume IX	Covariance Matrix Processor (CMP)
Volume X	State Transition Matrix Module (STMM)
Volume XI	Observation Computation Module (OCM)
Volume XII	Measurement Partial Derivative Module (MPM)
Volume XIII	Residual Computation Processor (RCP)
Volume XIV	Display Processor (DP)

VOLUME V

ORBIT DETERMINATION EXECUTIVE (ODE)

CONTENTS

FIGURE

ACRONYMS

BB	batch-to-batch
BBHT	batch-to-batch history table
CMi	a priori covariance matrix slot in the CST
CMP	covariance matrix processor
CP	convergence processor
CST	covariance storage table
DC	differential correction
DCE	differential correction edit
DCEHT	differential correction edit history table
DDD	digital display driver
DEP	data editing processor
DFCP	data file control processor
FFP	free-flight predictor
ID	identification
MCC	Mission Control Center
MED	manual entry device
MPT	mission plan table
OD	orbit determination
ODE	orbit determination executive
PBI	pushbutton indicator
PFNI	powered flight numerical integrator
RCP	residual computation processor
RF	radio frequency
SB	superbatch
SBHT	superbatch history table

SS1,SS2 SS3,SS4	automatic a priori covariance submodes
TDRS	tracking and data relay satellite
VAT	vector administration table
VDT	vehicle data table

1.0 CORRELATION TO LEVEL B

The logic structure presented herein is designed to satisfy the level B software requirements specified in sections 5.14, 6.0 (fig. 6-13), 7.2.13, and 8.3.13 of JSC IN 77-FM-57.

2.0 GENERAL DESCRIPTION

The orbit determination executive (ODE) shall provide the controlling logic for the low-speed (onorbit) orbit determination (OD) process and the ground navigation computation in the Shuttle Mission Control Center. There shall be three modes of OD; the differential correction edit (DCE) mode, the batch-to-batch (BB) mode, and the superbatch (SB) mode. The DCE mode shall provide the user with a hands-off capability to execute preliminary solutions for the purpose of editing batches of data. The BB mode shall provide a semiautomatic OD process in which the user can step through the data batches in a vehicle data table (VDT) batch by batch, exercising accept/reject decisions for each solution. The SB mode shall provide the user with an OD process in which a group of data batches shall be completely processed as a single data set before returning control to the system.

2.1 ODE FUNCTIONS

The ODE logic shall be constructed such that the user can apply any mode to any of several vehicles; however, only one ODE shall be in execution at a time. The specific functions provided by the ODE are as follows.

a. Provide all initialization for the OD, including setup of DCE, BB, and SB modes.

b. Provide the capability to accept manual control inputs.

c. Use the data file control processor (DFCP) to accomplish the following.

   (1) Automatically split a batch of data containing a powered flight segment defined in the mission plan table (MPT).

   (2) Ensure that no powered flight segments occur within the SB data span (excluding zero delta-V maneuvers).

   (3) Locate the batches to be processed and compile required descriptive data.

d. Propagate the input state vector to the anchor time, or output time, using the free-flight predictor (FFP) and/or the powered flight numerical integrator (PFNI).

   If superbatch end time propagation is requested, propagate the a priori state vector from anchor time, using the a priori values for all dynamic state vector elements.

881

e. Initialize contents and values of parameters in the solution.

(1) DCE mode - six elements (six components of spacecraft position and velocity)

(2) BB mode - six or nine elements (six components of spacecraft position and velocity and, upon option, three components of a vent spanning the entire interval)

(3) SB mode - six to fifteen elements, including six components of spacecraft position and velocity and, upon option, any combination of the following.

(a) A maximum of three vents over specified time intervals contained within the data arc (each vent consists of three components of the vent's force)
(b) Drag multiplier
(c) Up to nine data biases

f. Propagate any existing covariance matrix to the anchor time using the covariance matrix processor (CMP), or fetch vector independent covariance matrices from the covariance storage table (CST).

g. Use the CMP to construct the a priori covariance matrix from the 6x6 position and velocity portion of the propagated covariance matrix plus (as required) diagonal elements for data biases, drag multiplier, and 3x3 submatrices for vent elements. This includes coordinate transformations for the vector-independent covariance matrices from the CST.

h. Invert the a priori covariance matrix for the initialization of the normal matrix.

i. Use the convergence processor (CP) to compute the actual OD solution from a weighted least-squares fit of ground-based navigation tracking data.

j. In the DCE mode (or BB mode with edit option) use the data editing processor (DEP) to edit the batch of observations. If the set of edited observations changes, redo the OD up to a user-specified maximum number of times (edit loops).

k. Superbatch end time propagation of the output vector and covariance to output time using the free-flight predictor (FFP) and covariance matrix processor (CMP) respectively.

l. In the edit mode (DCE or BB with edit option), if more than the user-specified number of observations are flagged for exclusion (or if the state vector change is greater than a user-specified amount), illuminate a digital display driver (DDD) and cease processing data from this vehicle (DCE automatically accepts its solution and goes to the next batch unless an editing problem occurs).

m. When a solution has been accepted, store the results into the appropriate DC history table (differential correction edit history table (DCEHT), batch-to-batch history table (BBHT), or superbatch history table (SBHT)).

n. When the accept/reject decision for a BB solution has been entered, set up a work request for the next BB determination.

2.2 ODE STRUCTURE

The functional structure of the ODE is illustrated in figure 1. Note that the control logic for BB and DCE modes share common logic. In addition, note that the block OD is called in all modes. The EDIT block is called only in BB and DCE modes. The ODE structure is described in section 9.0 of this document. The OD is described in section 10.0, and EDIT is described in section 11.0.

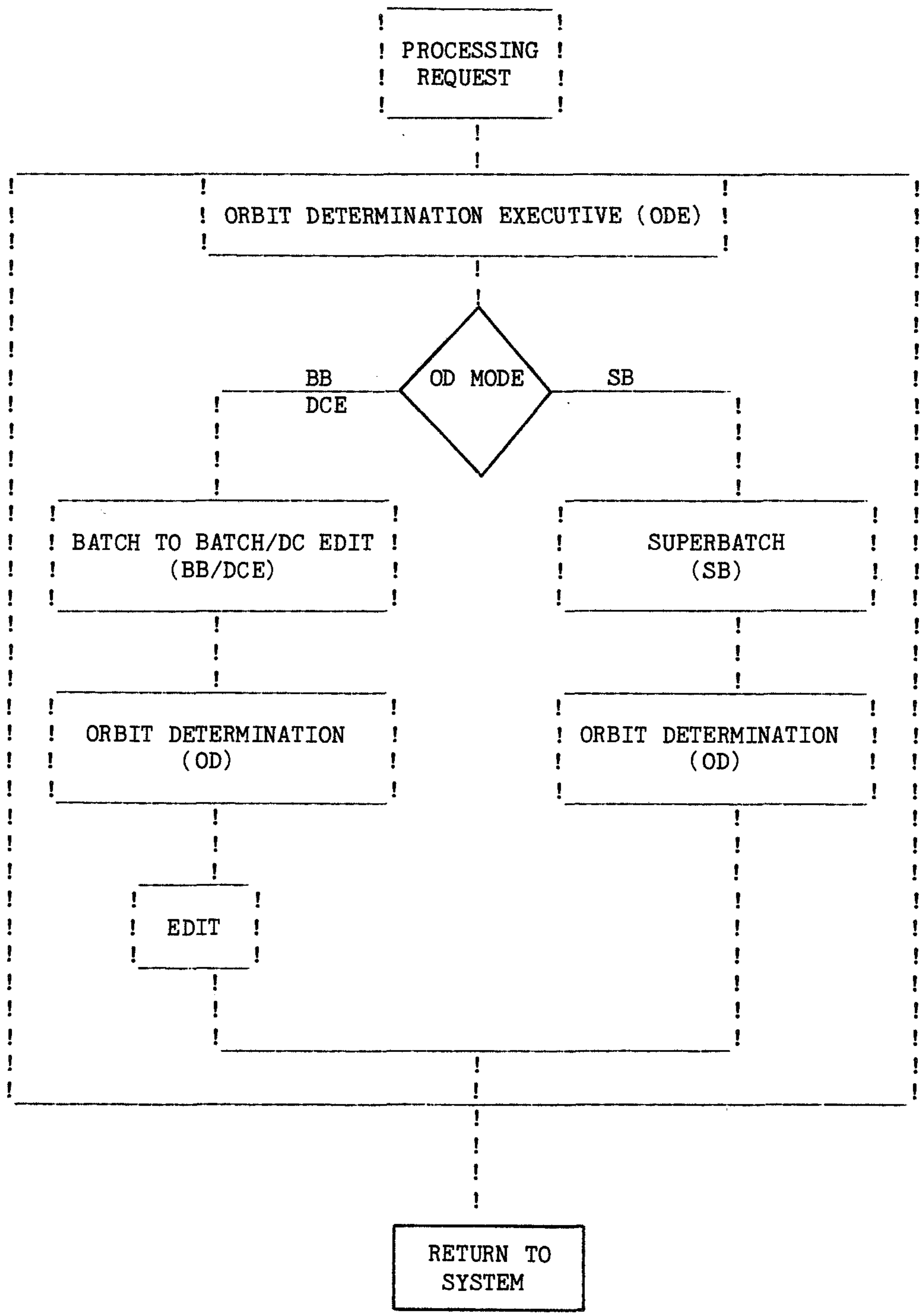

Figure 1.- Orbit determination functional logic.

3.0 HIERARCHY

Because of the multifunction use of the ODE and the high probability of several requests for the ODE in the system queue(s) at any one time, it is necessary to establish a hierarchy for the selection of the ODE work requests from the system queue(s). In general, SB functions shall have priority over BB functions, and BB functions shall have priority over DCE functions. For efficiency, the DCE shall operate on one vehicle VDT until all the data in that VDT have been edited. The DCE shall then proceed to the next vehicle's VDT. This procedure is intended to minimize the number of interchanges of data between mass data storage devices and the computer memory.

From time to time it will be necessary for the user to change specific ODE control parameters, and/or to respond to a requested decision. These entries shall be entered by means of the manual entry device (MED), and shall be processed asynchronous with the ODE queue(s).

4.0 LOW-SPEED NAVIGATION TRACKING DATA

The purpose of the ODE is to obtain a "best estimate" of the target vehicle's position and velocity by fitting the low-speed navigation tracking data in the weighted least-squares sense.

The term "low-speed" refers to the tracking data sample rate (i.e., the interval between consecutive data counter readouts). All navigation tracking data having a sample rate frequency no greater than one sample per second shall be considered to be low-speed.

These data shall consist of angle, range, and carrier radio frequency (RF) shift (Doppler) acquired by tracking a space vehicle from a ground receiving station either directly or via a relay satellite.

The objective of this section is to define the terminology concerning the low-speed navigation tracking data to be used in the remainder of this volume.

4.1 VDT

There shall be one VDT per DC link. Each VDT shall contain up to 100 batches of low-speed navigation tracking data. The VDT shall be ordered chronologically with respect to the batch time (time of the first valid observation within a batch). The remainder of this section is a detailed description of the contents of the VDT.

4.1.1 VDT Header Record

Each VDT shall contain the following data

a. DC link ID - identification of the DC link.

b. Tracking-type exclusion flags - six flags to indicate tracking types to be excluded from processing in one of the ODE modes.

(1) BB

(a) C-band
(b) S-band direct
(c) Relay

(2) SB

(a) C-band
(b) S-band direct
(c) Relay

4.2 DATA BATCHES

The data batches have a header record and a data record that contains up to 100 time-tagged observation data frames.

4.2.1 Batch Header Record

a. ID codes

(1) Batch ID

(2) Original DC link of batch

(3) Support ID code

(4) Vehicle ID

(5) Receiver station ID

(6) Transmitter station ID

(7) Forward link relay satellite

(8) Return link relay satellite

(9) Forward link ground antenna ID, return link ground antenna ID.

(10) Return link relay satellite frequency

(11) Tracking type

(a) C-band skin
(b) S-band direct: N/S two-way
(c) S-band direct: E/W two-way
(d) S-band direct: N/S three-way

(e) S-band direct: E/W three-way
(f) Relay: two-way/three-way
(g) Relay: hybrid

(12) Live-sim indicator

b. Frequency

(1) Reference frequency

(a) S-band-direct = two-way transmitter frequency from transmitting station's incoming data message

(b) S-band direct = three-way receiving station's estimate of the transmitter frequency from receiving station's incoming data message

(c) Transmitter direct frequency = user input value of transmitter frequency to be used for processing three-way direct Doppler data.

(d) Relay = target vehicle transmitter frequency

(2) bF_p - return relay link translation frequency

c. Transponder delays

(1) Target vehicle

(2) Forward link relay satellite

(3) Return link relay satellite

d. Bias values (total correction applied by the bias correction processor)

(1) Time

(2) Range

(3) Angle 1

(4) Angle 2

(5) Doppler

e. Processing flags

(1) Alien - indicates that batch was originally from another DC link

(2) Exclude/BB - indicates that batch is to be excluded from BB processing

(3) Exclude/SB - indicates that batch is to be excluded from SB processing

(4) Invalid three-way flag - used to inhibit processing of a three-way direct batch until user has input a transmitter ID and a transmitter frequency

(5) DCE - indicates whether batch has been processed by the DEP

f. Miscellaneous

(1) Doppler model coefficient K: Nominally 1000ω_4 (S-band direct), 1000 (S-band relay), 100 (K-band relay). However, if the LSIP divides Doppler by 1000/100, K = ω_4 (S-band direct, 1 (relay). Here ω_4 = target vehicle transponder ratio

(2) Doppler bias frequency (ω_3) - effective bias frequency used in receiving ground station's Doppler counter subsystem

(3) Range ambiguity interval (A_R)

g. Data information

(1) Batch time - time tag of first valid observation

(2) Final time of data - time tag of last valid observation

(3) Total number of data frames

(4) Number of valid observations

(a) Range
(b) Angle
(c) Doppler

(5) Number of edited observations

(a) Range
(b) Angle
(c) Doppler

4.2.2 Data Record/Data Frame

The data record portion of a data batch shall contain up to 100 data frames. Each frame will contain values for the following information:

a. Time tag - provided by receiving station

b. Angle 1 - azimuth or X-angle

c. Angle 2 - elevation or Y-angle

d. Range - round trip range

e. Doppler - difference between counter readouts divided by the sampling interval

f. Tau - Doppler counter sampling interval (or compression interval if specified by user)

g. Edit flags - one for each of the data fields (angle 1, angle 2, range, and Doppler)

4.3 OBSERVATION

Each parameter identified in the data frame (sec. 4.2.2) as angle 1, angle 2, range, and Doppler (in general) shall be referenced as an observation. When an observation is defined for a given format but is invalid for a particular data frame, it shall be replaced by a filler value.

Observation	C-band	Direct S-band	Relay
Angle 1	Azimuth	X-angle	--
Angle 2	Elevation	Y-angle	--
Range	Round trip	Round trip	Round trip (module A_R)
Doppler	--	$\frac{\Delta C}{\tau}$	$\frac{\Delta C}{\tau}$
Doppler count interval	--	τ	τ

where

A_R = range ambiguity interval

ΔC = difference between two samples of the frequency counter at the receiving station

τ = the time interval between frequency counter samples used in the computation of ΔC

5.0 SOLUTION VECTOR

The solution vector shall delineate the size and contents of the state vector within the ODE. The order of the elements of the covariance matrix are also defined by this vector.

The following defines the contents of the solution vector.

Position - three elements, Cartesian mean of 1950, $\vec{R} = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$

Velocity - three elements, Cartesian mean of 1950, $\vec{V} = \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{z} \end{bmatrix}$

Vent(i) - three elements, Cartesian vehicle body axis; i = 1, 2, or 3 (one, two, or three sets of parameters, each set consisting of three force components referenced to vehicle body coordinate system).

Drag multiplier - single element, scalar multiplicative factor for the drag in the integration force model.

b_j - biases for relayed Doppler observations, j = 1,2,...,9

where

j	Forward relay link	Return relay link
1	TDRS E	TDRS E
2	TDRS S	TDRS S
3	TDRS W	TDRS W
4	TDRS E	TDRS S
5	TDRS E	TDRS W
6	TDRS S	TDRS E
7	TDRS S	TDRS W
8	TDRS W	TDRS E
9	TDRS W	TDRS S

b_1, b_2, and b_3 are two-way/three-way relayed Doppler biases and the remainder are hybrid relayed Doppler biases.

The solution vector shall define from 6 to 15 elements, based on user MED inputs and ODE mode (SB, BB, or DCE). Position and velocity shall always be present. In the interest of simplicity, the overall order of the solution vector should remain fixed as there shall be several pieces of software using it. With a fixed order, the contents of the solution vector can be reduced to 13 pieces of binary information.

6.0 A PRIORI STATE VECTOR

6.1 TERMINOLOGY

A state vector in the ODE shall refer to the vector of numeric values for position velocity components, vent forces, drag multiplier, and/or data biases. State vectors are variable in length from 6 to 15 elements (the first 6 elements are always associated with position and velocity). There shall always be a time tag (epoch) for a state vector, and each vent shall be defined by a time interval.

Because a state vector has variable content, it shall be necessary to have a means to define the content. Within the ODE the means of identification is the solution vector (sec. 5.0). External to the ODE the name "solution vector" no longer has significance, and it shall be assumed that there is a vector of definitions associated with every state vector. Implicit in each solution vector is the fact that the first six elements of every state vector must be position and velocity.

Further definitions

a. Anchor time - time associated with computed results within the ODE. All ODE computations take place at the time tag of the earliest valid observation being processed.

b. Output time - time associated with the output results. For BB and DCE modes, this is the time of the earliest valid observation. For the SB mode, the output time may also be the time of the last observation.

c. Input state vector - the input state vector that shall provide the initial position and velocity information for the OD. This vector shall be obtained from one of the sources defined in section 6.2.

d. A priori state vector - this state vector contains the initial estimate of the values for the ODE solution at the initial time of the data arc.

e. Output vector - state vector at output time as a result of the solution.

f. Dynamic parameters - those elements of a state vector that affect the propagation of the position and velocity from one time point to another (i.e., affect the trajectory). For discussion of the ODE, position and velocity shall be excluded and the dynamic parameters restricted to vent forces and drag multiplier.

6.2 INPUT STATE VECTOR RETRIEVAL

The user shall provide an identification for the input state vector. This source shall be stored in the appropriate control table and used to retrieve the input state vector.

A standard routine (system routine) shall provide access to all input state vectors. These vectors (and their associated time tags) shall be found in one of the following sources.

a. Vehicle MPT trajectory profile

b. Vector administration table (VAT)

c. DCEHT

d. BBHT

e. SBHT

f. ODE control tables (DCE, BB, and SB)

The position and velocity elements of the vector obtained in this manner shall be transformed (if necessary) to Cartesian mean-of-1950 elements and the entire vector stored in the appropriate ODE control table as the input state vector plus time tag.

State vectors obtained from the vehicle MPT trajectory profile, VAT, DCEHT, and the DCE control tables shall contain only six elements of position and velocity. The state vectors from the BBHT and BB control tables may have six or nine elements. The three additional elements shall be a vent force for all BB-related state vectors. All the remaining sources have variable length and content state vectors, the contents of which are identified (as discussed) in section 5.0.

6.3 GENERATION OF THE A PRIORI STATE VECTOR

There are two distinct portions of the a priori state vector: the initial value for position and velocity, and the initial values for the remainder of the vector.

6.3.1 Position and Velocity

The position and velocity components of the a priori state vector shall be Cartesian mean of 1950, and shall be obtained as follows.

a. Use the input state vector from the appropriate control table.

b. Modify the position, $\vec{R}$, and the velocity $\vec{V}$, by the user-specified change to the semimajor axis, Δa, which is also stored in the control table. The required computations are

$$R = |\vec{R}| = (x^2 + y^2 + z^2)^{1/2}$$

$$V = |\vec{V}| = (\dot{x}^2 + \dot{y}^2 + \dot{z}^2)^{1/2}$$

$$a = \left(\frac{2}{R} - \frac{V^2}{\mu}\right)^{-1}$$

$$\vec{R}' = \left(\frac{a + \Delta a}{a}\right) \vec{R}$$

$$\vec{V}' = \left(\frac{a}{a + \Delta a}\right)^{1/2} \vec{V}$$

where

μ is the gravitational constant of the Earth

$\vec{R}'$, $\vec{V}'$ are the modified values of $\vec{R}$ and $\vec{V}$

c. If the time tag of the input state vector is different from the anchor time, propagate $\vec{R}'$ and $\vec{V}'$ to anchor time with the specified integrator options. If there are dynamic parameters in the input state vector they shall be considered in propagation.

d. The resultant Cartesian mean-of-1950 position and velocity at anchor time is stored as the a priori position and velocity in the control table.

6.3.2 Additional Elements

Superbatch a priori values for vent forces (and the associated start and stop times), drag multipliers, and data biases shall be entered by the user via MED. Time intervals for SB vents shall be required user input. BB solutions shall always use the value of zero for a priori vent forces, and the start and stop times shall be set to the time interval spanned by the data batch.

7.0 A PRIORI COVARIANCE MATRIX APPLICATION

7.1 INTRODUCTION AND TERMINOLOGY

a. BB Mode

There are four automatic submodes used for determination of the a priori covariance. In the SS1 submode, no a priori covariance is used. In the SS2, SS3, and SS4 submodes, the CMP is instructed to construct an a priori covariance.

The solution vector in the BB mode contains either six or nine elements. If it is nine elements, it contains one vent. In all submodes (except SS1) the CMP constructs a 6x6 M50 Cartesian state covariance $C(t_A)$ (valid at a priori time t_A) as instructed, and appends (if instructed) the 3x3 vent covariance, BCOV. The a priori covariance, $\Lambda(t_A)$ (returned by the CMP) is either 6x6 or 9x9 and has the general form

$$\Lambda(t_A) = \left(\begin{array}{c|c} C(t_A) & \underset{6x3}{0} \\ \hline \underset{3x6}{0} & BCOV \end{array}\right)$$

Specific definitions of the four automatic submodes are given below.

(1) SS1 submode - No a priori weighting is used in the OD process (i.e., the ODE sets $\Lambda^{-1}(t_A) = 0$) (6x6 or 9x9).

(2) SS2 submode - The covariance matrix SS2 (6x6) stored in the CST is used to construct the a priori covariance. This matrix is time-tagged at t_A, and the CMP uses the a priori position and velocity vector $\vec{X}_A$ to transform the matrix SS2 to $C(t_A)$ in M50 coordinates. If a vent is specified in the solution vector, BCOV is appended to $C(t_A)$ to obtain $\Lambda(t_A)$

(3) SS3 submode - This submode is identical to SS2 except that the covariance matrix SS3 from the CST is used to construct the a priori covariance matrix.

(4) SS4 submode - The output (or "solution" covariance from the previous data batch) is propagated to the anchor time of the current batch; only the 6x6 partition (Cartesian position and velocity covariance) is propagated by the CMP. If a vent is specified in the solution vector, BCOV is appended as above following propagation.

In addition to these four automatic submodes, the user may specify that any of the vector-independent matrices stored in the CST be used to construct the a priori covariance. In this case, Λ_A is constructed as in the SS2 and SS3 submodes.

b. DCE mode

The procedure for the DCE mode is identical to the BB mode except that the solution vector is limited to the six-dimension Cartesian position and velocity elements only. The SS4 automatic submode is not applicable to the DCE mode.

c. SB mode

The methods for constructing the a priori covariance matrices in the SB mode bear the same names as those used for the BB mode. However, the definition of SS4 is considerably different, and the CST slots S1COV or S2COV are used to obtain the "appended" parameter covariance elements.

The maximum allowed dimension of the SB solution vector is 15 (i.e., up to 9 dynamic parameters and/or observation bias elements may be used). The CMP constructs $C(t_A)$ = (6x6 M50 Cartesian position and velocity covariance at anchor time) as instructed (see below). Elements in S1COV or S2COV (only one of these is specified) are then appended (in solution vector order) to $C(t_A)$ to obtain the a priori covariance matrix $\Lambda(t_A)$.

The contents of SnCOV (n = 1,2) are as follows.

CV_n = 3x3 vent covariance

σ_{Dn}^2 = drag multiplier variance

σ_{b2n}^2 = two-way/three-way relay Doppler bias variance

σ_{bHn}^2 = hybrid relay Doppler bias variance

Example: Suppose that the solution vector specified the following parameters.

Element	Parameter
7 - 9	Vent 1
10 - 12	Vent 2
13	Drag multiplier
14	Two-way/three-way bias for a given TDRS pair
15	Hybrid bias for a given TDRS pair

If SnCOV is specified, the CMP constructs the a priori covariance.

$$\Lambda(t_A) = \left[\begin{array}{c|c|c|c|c|c} C(t_A) & \underset{6x3}{0} & \underset{6x3}{0} & \underset{6x1}{0} & \underset{6x1}{0} & \underset{6x1}{0} \\ \hline \underset{3x6}{0} & CV_n & \underset{3x3}{0} & \underset{3x1}{0} & \underset{3x1}{0} & \underset{3x1}{0} \\ \hline \underset{3x6}{0} & \underset{3x3}{0} & CV_n & \underset{3x1}{0} & \underset{3x1}{0} & \underset{3x1}{0} \\ \hline \underset{1x6}{0} & \underset{1x3}{0} & \underset{1x3}{0} & \sigma^2_{Dn} & \underset{1x1}{0} & \underset{1x1}{0} \\ \hline \underset{1x6}{0} & \underset{1x3}{0} & \underset{1x3}{0} & \underset{1x1}{0} & \sigma^2_{b2n} & \underset{1x1}{0} \\ \hline \underset{1x6}{0} & \underset{1x3}{0} & \underset{1x3}{0} & \underset{1x1}{0} & \underset{1x1}{0} & \sigma^2_{bHn} \end{array}\right]$$

The methods of a priori covariance construction specified by the ODE for the SB mode are given below.

(1) SS1 - No a priori covariance (i.e., $\Lambda^{-1}(t_A) = 0$)

(2) SS4 - In this case, a vector-dependent covariance is specified for the a priori covariance matrix construction (see sec. 7.2 for possible storage locations).

The a priori state vector, $\vec{X}_A$, is required to be derivable (via propagation) from the vector associated with this covariance. The CMP propagates the 6x6 matrix $C(t_E)$ = (upper left 6x6 partition of specified covariance) from its time of reference, t_E to the anchor time. The resulting matrix, $C(t_A)$, is then augmented (as defined above) with elements of S1COV or S2COV to obtain $\Lambda(t_A)$.

(3) Specify a vector-independent covariance - Any one of the 6x6 vector-independent matrices stored in the CST is specified for the a priori covariance matrix construction. The a priori state vector, $\vec{X}_A$, is used to obtain $C(t_A)$.

d. Downweight option

After the covariance $\Lambda(t_A)$ has been supplied by the CMP, the ODE may be required (per user input) to downweight this matrix as follows.

$$\Lambda_A = K^n \Lambda(t_A)$$

K = KGAMMA downweight multiplier (nominal value = 2)

n = Number of times the KGAMMA PBI has been depressed by user (prior to execution of the ODE)

The matrix Λ_A is then used as the a priori covariance in the differential correction (DC) process. The parameter n in the appropriate control table is reset to zero after this computation. The downweight option is not applicable for SS1 solutions in any mode.

7.2 FUNCTIONAL REQUIREMENTS

7.2.1 Specification of Input Covariance

A covariance matrix in one of the following storage locations is specified (to the CMP) to be used in constructing $C(t_A)$.

a. CST - slots SS2, SS3, CM1-CM4 contain only 6x6 vector-independent matrices in any of the three available coordinate systems.

b. BBHT - contains either 6x6 or 9x9 (one vent) vector-dependent matrices in standard internal coordinates.

c. SBHT - contains vector-dependent (up to 15x15) matrices in standard internal coordinates.

d. DCEHT - contains 6x6 vector-dependent matrices in standard internal coordinates.

e. Solution control table - contains current DC solution (BB, SB, or DCE) covariance matrix (vector-dependent) in standard internal coordinates.

In the BB mode, the BCOV vent covariance is specified if a vent is specified in the solution vector. In the SB mode, either S1COV or S2COV is specified for constructing the "parameter elements" section of the covariance $\Lambda(t_A)$.

Note: In the SS2, SS3, or CMi application submodes (where a vector-independent covariance is specified), the ODE normally supplies $(\vec{X}_A, t_A)$ to the CMP.

7.2.2 Powered Flight

If one or more MPT burns occur in the time interval (t_E, t_A) over which the covariance matrix is to be propagated, the ODE must supply the following data to the CMP.

$\vec{X}_{TIG_n}$ = M50 state at ignition time of burn number n

T_{TIG_n} = Ignition time of burn number n

The ODE may specify identification (ID) codes indicating where these data are located.

7.2.3 KGAMMA Downweight

The covariance $\Lambda(t_A)$ is returned to the ODE from the CMP. If the user has depressed the KGAMMA PBI n times prior to execution of the current DC solution, the OD computes

$$\Lambda_A = K^n \Lambda(t_A)$$

The matrix Λ_A^{-1} is supplied to the CP for a priori weighting in the DC solution. The parameter n in the appropriate control table is reset to zero after this computation. The downweight option is not applicable for SS1 solutions in any mode.

8.0 MED INPUT

The user shall have the capability to input or change the contents of any one of the control tables at any time (including the control table for a DC link/mode that is in execution). A change during execution time shall not alter the parameters being used by an OD already in execution but shall be used for the next ODE execution with the specified DC link and mode. New MED values shall not affect the controls to be used for the FORCE option to any ODE mode.

9.0 ODE CONTROL

The ODE control logic shall provide entry into the proper mode/function (i.e., SB, BB, or DCE). The operations performed are described in the following paragraphs.

ODE CONTROL shall first obtain the requested DC link and switch on the "OD IN PROGRESS" DDD. If, at this point, the DC link has not been initialized, an error message shall be set, displays queued, the "OD IN PROGRESS" DDD switched off, and control returned to the system.

If the DC link has been initialized, error flags and message indicators shall be reset. The proper control table shall then be loaded according to what mode has been requested (i.e., if an SB mode is requested, the SB control table is loaded, and control is passed to the SB function logic). Note: If the BB mode is requested the DCE flag shall be set to "NO."

9.1 DCE FUNCTION

The purpose of the DCE function shall be to provide a mechanism for the automatic editing of the bulk of the ground-based navigation tracking data. The DCE shall be able to recognize the occurrence of certain problems and excessive noise in the data, and request the user to intervene. The user shall have the following decision functions at his disposal.

DCE accept - accept the current results and proceed

DCE reject - delete the batch from the VDT and proceed as if the batch never existed

DCE execute - redo the solution (the user may change control parameters or data edit status prior to this decision)

DCE force - perform one more iteration with no additional editing

Another adjunct to the DCE shall be the DCE initialize function that shall initialize the DCEHT, control table, and initiate the automatic DCE process.

Prior to execution of a DCE for any DC link, the user must cause the DCE control table for that link to be initialized. Once started, the DCE process shall automatically step through (chronologically) all unedited data batches (in that vehicle's VDT) that have an initial time equal to or greater than a user-supplied start time.

Automatic sequencing through the data batches shall continue for the specified DC link until

a. The user deactivates the DCE for the specified DC link.

b. No unedited data batches exist for the specified DC link.

c. An error is encountered (an editing problem).

The automatic processing of the data batches that have been interrupted for the above reasons, respectively, shall be reinitialized when

a. The user reactivates the DCE for the specified DC link.

b. A new data batch is placed in the VDT.

c. The user provides a decision via the pushbutton indicator (PBI).

9.1.1 DCE Initialize

A MED input to initialize the DCE function for a user-specified DC link shall cause the following action to be taken.

a. Load the required DC link (if necessary) and verify that the DC link has been initialized.

b. Reset error flags and message indicators.

c. Set the ODE to use the DCE control table and set the DCE flag to "YES."

If problems are encountered in initializing the above items, a message shall be sent to the user explaining what is wrong, and the ODE shall return control to the system.

If no problems are encountered, the initialization shall

a. Search the array indicated by the DCE control table for the required six-element state vector. (If for some reason a state vector cannot be found, the ODE shall set an error message and return control to the system.)

b. Move the state vector (and its time) into the DCE control table. If necessary, transform the state vector to Cartesian mean of 1950 (MOF50).

If the requested solution type requires an a priori covariance matrix

a. Use the CMP to provide this matrix to the DCE control table. If this matrix is not available, set an error message and return control to the system.

b. Use the DFCP to locate the first data batch with an initial time greater than or equal to its user-specified start time. If no such batch exists, set an error message and return control to the system; otherwise, continue processing.

c. Zero the contents of the DCEHT. (Note: The state vector and covariance matrix must be in the control table prior to destroying the DCEHT.)

d. Enter a work order in the DCE queue for the ODE to perform a DCE on this link.

e. Set the initialization flag to indicate that the DCE has been initialized.

f. Set the decision waiting flag to "NO."

g. Return to the system.

9.1.2 DCE Auto Mode

The purpose of the DCE AUTO mode entry to the ODE is to provide control for the automatic editing of the ground-based navigation tracking data. The following is a general outline of the required functions for the DCE.

a. Verify the validity of the DCE work request.

b. Use the DFCP to obtain the appropriate data batch from the VDT.

c. Initialize the OD from the DCE control table.

d. Use the OD to generate ephemerides and compute residuals.

e. Use the edit routine to edit the data in the batch.

f. Use the OD to generate a new estimate of the target vehicle's position and velocity and to compute data residuals based on the new estimate.

g. Repeat steps (e) and (f) until the editing criteria are satisfied. (The EDIT routine shall store the edited data batch into the VDT when these criteria are satisfied.)

h. Unless prevented by some failure or edit test, accept the DCE solution and store the results in the DCEHT.

i. Issue a work request for the DCE AUTO to process another data batch.

j. Issue a BB work request for this DC link.

k. Return control to the system.

9.1.2.1 DCE Work Request Validity

The following test and decisions shall be performed prior to processing any data with the DCE.

a. If the DCE has not been activated for the specified DC link, place a work request in the queue for the BB to process a batch from this DC link, and return to the system.

b. If the DCE has not been initialized for the specified DC link, return to the system.

c. If the DCE decision waiting flag has been set for the specified DC link, return to the system.

d. If there is not an unedited batch with a batch time greater than the user-specified minimum DCE time for the DC link, return to the system.

9.1.2.2 DCE Processing

In execution, the DCE AUTO shall loop through several processors to accomplish data editing. The OD routine (sec. 10.0) shall perform several tests to determine if the DCE can be accomplished, prepare initial state and covariance data, and utilize the RCP and CP to obtain a set of residuals to edit.

The DCE AUTO shall loop through the OD and EDIT routines (sec. 11.0) until either the DEP fails to change the edit status of a single point or an error occurs.

Error conditions shall be as follows.

a. DEP indicates a data edit problem.

b. An error flag from the OD.

c. Exceeding the allowed number of edit loops.

The DCE shall ensure that the final estimate of the state vector is based on the data batch in its final edited status.

When the OD EDIT looping process is complete, the EDIT routine shall use the DFCP to copy the DCE version of the current data batch into the VDT. This includes the "batch edited" flag and the number of points deleted by the DEP in the data batch header record.

The DCE processing shall then continue with the following.

a. Test the quality of the convergence. A test shall be made to determine whether or not there has been too great of a change in the state vector (sec. 8.4). Also, a test shall be made to see if the mean and standard deviation of the converged residuals fall within user-specified limits.

b. If an error flag has been set, or if a quality test has been failed, the DCE decision waiting flag shall be turned on, the DCE problem light (DDD) activated, a display queued, and control returned to the system. This exit shall suspend the automatic sequencing feature of the DCE function for this DC link. (Note: Suspending the DCE is not the same as deactivating the DCE.)

c. If no error flags have been set, and the quality tests have been passed, the DCE shall automatically proceed to the DCE accept logic. Normally, the DCE function shall automatically step through all data batches in the VDT for any one vehicle. Once the automatic sequencing feature is suspended, the user shall have to respond to reinitiate the automatic sequencing. User responses shall be to either accept the current results and continue (DCE ACCEPT), delete the current batch of data from the VDT and continue (DCE REJECT), or repeat the process for the current batch (DCE EXECUTE). DCE FORCE shall not necessitate the automatic sequencing through the data batches.

9.1.3 DCE ACCEPT

The DCE ACCEPT entry into the ODE is a user response exercised after the automatic sequencing of the DCE function has stopped and the DCE decision waiting flag has been set for a DC link. Normal termination of the DCE occurs when no problems have been encountered. The purpose of the manual entry is for the user to accept the results of the DCE even though the logic has balked. When the DCE ACCEPT entry is requested for a specific link, the logic shall.

a. Send a descriptive message to the user, and return control to the system if the work request is a manual entry and the DCE decision waiting flag has not been set for the identified DC link.

b. Write a record in the DCEHT for this DC link. The information required for the DCEHT (sec. 14.0) shall be obtained from the DCE control table.

c. Cause a work order to be placed in the DCE queue for the ODE to be entered at DCE AUTO for a DCE on this DC link.

d. Turn off the DCE decision waiting flag and DDD.

e. Cause a work order to be placed in the BB queue for a BB solution on this DC link.

f. Return control to the system.

9.1.4 DCE REJECT

The DCE REJECT entry into the ODE is a user response exercised only after the automatic sequencing of the DCE function has stopped and the DCE decision waiting flag has been set for a DC link. The purpose of this entry is to delete from the VDT the batch of data just processed and resume automatic DCE processing. When the DCE REJECT entry is requested for a specific DC link, the logic shall

a. Send a descriptive message to the user and return control to the system if the DCE decision waiting flag has not been set for the identified DC link.

b. Use the DFCP with the identification of the current batch to delete the batch from the VDT.

c. Restore data from the last accepted entry in the DCEHT into the current solution information data.

d. Cause a work order to be placed in the DCE queue for the ODE to be entered at DCE AUTO for a DCE on this DC link.

e. Turn off the DCE decision waiting flag and DDD.

f. Return control to the system.

9.1.5 DCE EXECUTE

The DCE EXECUTE entry into the ODE is a user-response entry. The purpose of this entry is to repeat the DCE process on the same data batch that was just processed. When the DCE EXECUTE entry is requested for a specific DC link, the logic shall

a. Send a descriptive message and return control to the system if the DCE decision waiting flag has not been set for the identified DC link.

b. Capture control parameters and input data for the control table.

c. Perform the DCE OD using the same data batch identifications as for the previous DCE. At this point the processing is identical to the DCE processing logic (sec. 9.1.2.2).

9.1.6 DCE FORCE

The purpose of the DCE FORCE entry is to force one additional iteration in the CP. This entry is a user-response entry to the decision waiting condition in the DCE. No additional editing shall be performed in response to the DCE FORCE.

When the DCE FORCE entry is requested by the user for a specific DC link, the logic shall

a. Send a descriptive message and return control to the system if the DCE decision waiting flag has not been set for the identified DC link.

b. Directly enter the DCE processing logic at the OD routine to perform one iteration (without edit) as a continuation of the preceding DCE's postedit OD.

c. If no errors are encountered (excessive state vector change, nonsatisfactory converged residuals), return control to the system.

d. The DCE shall remain in the decision waiting status upon conclusion of the DCE FORCE.

9.2 BB FUNCTION

The purpose of the BB function is to perform a fit over a single batch of ground-based navigation data. The BB process is semiautomatic for a particular DC link in that the user's acceptance or rejection of a batch shall queue the processing of the next batch.

The anchor time and output time for each batch shall be the time of the first valid data point in the batch.

The BB solution vector associated with this anchor time shall consist of either six or nine elements. The six-element (position and velocity) state vector shall always be present. Optionally, three components of vent force (for a vent over the entire batch) shall be included. The BB function may, at user's option, automatically edit the data within each batch processed. There shall also be an interface between the BB and the DCE functions. If the DCE is active for the same DC link as the BB, the BB function will not process a particular batch of data until it has been edited by the DCE.

The BB mode user may invoke the following control functions.

a. BB accept - accepts the results of the batch just processed.

b. BB reject - rejects the results of the batch just processed and deletes the batch from the VDT.

c. BB execute - processes the batch currently in the ODE work area. Always a repeat (with modified parameters) of a previous process.

d. BB rechain - restarts the BB processor.

e. BB force - forces one additional iteration in the OD function over the current batch.

A required part of the BB process shall be the BB initialize function, which shall contain the logic to preset the BB history and control tables. This function shall begin the semiautomatic BB process by invoking the BB execute function for the desired batch of data within the specified link.

9.2.1 BB INITIALIZE

The BB initialize MED input shall specify the DC link, the start time, and the initial state vector location. Upon receipt of the MED, the BB initialize function shall move the MED's parameters into the BB control table. The input state vector shall be moved to the BB control table and stored as initialization data. If errors are encountered in this fetch and store, appropriate messages shall be displayed and control returned to the system. The a priori covariance and inverted KGAMMA degraded slots of the current solution section shall be zeroed.

The state vector ID shall be set to use the current solution of the BBCT as input in the OD function.

The DFCP shall then be called to locate the first batch of data for the selected link whose start time is greater than or equal to the control table (MED) start time. If no data are found, a message shall be sent to the user, and processing shall continue.

The BB history table shall then be cleared for the selected link, and a work request shall be issued to the BB queue for this DC link.

A flag shall then be set to indicate that initialization has been completed, the decision waiting flag set to "NO" (=0) and control returned to the system.

9.2.2 BB Execute

The BB execute entry may be requested as the continuation of a specific ODE function, or it can be requested via MED to repeat the processing of a batch of data (with possible modification of any BB control table parameters except the batch identifier).

9.2.2.1 BB Manual Execute

Whenever BB EXECUTE is requested directly by the user, the BB decision waiting flag shall be tested. If the flag is on, control parameters and MED's shall be loaded if a temporary covariance override submode has been requested, the covariance override flag shall be set. The edit loop counter shall be zeroed, and processing shall proceed with the OD function; otherwise, a message shall be sent to the user and control returned to the system.

If the BB edit option has not been requested, the OD function shall be used to compute the update to the state vector. Control shall then be returned to the ODE routine where, if the error mode is not equal to 1, display parameters shall be computed and the decision waiting flag set to "YES" (=1). The ODE shall return control to the system.

If the BB edit option has been requested, the process shall loop through the OD and EDIT functions until DEP fails to change the edit status of a single point, or until an error occurs. Editing shall be performed before using the CP.

Error conditions shall be as follows.

a. Too much data edited away

b. An error flag from the OD

c. Exceeding the allowed number of edit loops

The BB processor shall ensure that the final estimate of the state vector and data statistics are based on the data batch in its final edited status.

Detection of an error shall cause a message to be sent to the user. In any case, the DCFP shall be called to copy the edited batch of data into the VDT, the BB edit flag shall be turned off, a display of the results shall be queued, the BB decision waiting flag shall be turned on, and control shall be returned to the system.

9.2.2.2 BB Automatic Execute

When the BB EXECUTE is requested automatically, and the decision waiting flag is set to "NO," the next batch (not excluded) in the VDT shall be processed as follows.

a. Use the DFCP to locate the next batch and return the batch ID, start time, time of last valid observation, time span, relay satellite identification, and error flags. If this is the first call after initialization, use the batch information obtained by the BB initialization function.

b. If the DCE is not active for this DC link, the DFCP shall be used to set an edit flag in the batch header record.

c. If the DCE is active (and the batch has not been edited) a work request for the DCE shall be queued, a message shall be sent to the user, and control returned to the system.

d. Otherwise (the batch has been edited, or the DCE is not active for this link), a BB solution ID shall be assigned, the control parameters and MED's shall be captured, and the OD function called to perform the OD.

The process shall then continue through the same OD and EDIT logic described in section 9.2.2.1, BB MANUAL EXECUTE.

9.2.3 BB ACCEPT

The purpose of the BB ACCEPT entry is to approve the results of the batch just processed by the BB function. When the BB ACCEPT entry is requested by the user for a specific DC link, the ODE shall

a. Test the status of the BB decision waiting flag for that link. If it is not "YES", a message is sent to the user, and control is returned to the system.

b. Otherwise, store the current results into the BBHT.

c. Change the initial state vector location indicator in the BB control table to point to the most recent history table entry.

d. If the SS4 option has been requested by the user, change the initial covariance matrix location indicator in the BB control table to point to the most recent history table entry.

e. Set the BB decision waiting flag to "NO" (=0).

f. Issue a work request for the BB on this link, and return control to the system.

9.2.4 BB REJECT

The purpose of this entry into the ODE is not only to reject the results of a batch just processed, but to reject the data batch that caused the results. When the BB REJECT entry is requested by the user for a specific DC link, the ODE logic shall

a. Test the status of the BB decision waiting flag for that link. If it is not "YES", a message shall be sent to the user, and control shall be returned to the system.

b. Call the DFCP with the current batch ID and delete the batch from the VDT.

c. Flag the current solution as rejected.

d. Issue a work request to the BB queue for this DC link.

e. Set the BB decision waiting flag to "NO" (=0), and return control to the system.

9.2.5 BB RECHAIN

The BB RECHAIN entry into the ODE is a special entry that provides the user with the capability to restart the BB function and, if so desired, restart at a different data batch. When the BB RECHAIN entry is requested by the user for a specific DC link, the ODE logic shall

a. Utilize the DFCP to locate the user-specified batch. If the requested data batch does not exist in the VDT, an error message shall be sent to the user and control shall be returned to the system.

b. Search the BBHT for this link to find the data batch immediately preceding the rechain batch. If there are no batches in the BBHT preceding the rechain batch, the ODE logic shall turn off the BB decision waiting flag, go to the BB INITIALIZE function and proceed from there. If the data batch preceding the rechain batch is found, the ODE shall set the BBHT pointer to the end of that batch. The source of the input state vector shall be set to the entry in the BBHT preceding the rechain batch.

c. If a new input covariance matrix is desired, the location of that matrix shall also be moved into the BB control table.

d. Reset the BBHT to remove solutions that follow the rechained batch.

e. Issue a work request to the BB queue for this DC link, and return control to the system.

9.2.6 BB FORCE

The purpose of the BB FORCE entry is to force one additional iteration in the CP. No additional editing shall be executed by the BB FORCE.

When the BB FORCE entry is requested by the user for a specific DC link, the ODE logic shall

a. Test the status of the BB decision waiting flag for that link. If it is not "YES", a message is sent to the user and control is returned to the system.

b. Directly enter the OD function that, in turn, shall reload its exit values and execute one additional iteration.

c. Place a request in the system queue for a display of the results.

d. Return control to the system.

9.3 SB FUNCTION

The purpose of the SB function shall be to provide the ODE logic, which controls the low-speed OD using multiple (1 to 50) batches of navigation tracking data as a single data set, with a variable solution vector. There shall be no automatic sequencing through sets of data or automatic storage of solutions from the SB mode. Initiation of each execution, and the operating parameters for the execution, shall be manually controlled by the user. The user shall have the ability to save the results of an SB solution in the SBHT (sec. 14.0), but the user shall initiate the activity manually.

The user shall have the following manual controls for the SB mode.

a. ACCEPT - store the current results in the SBHT

b. FORCE - cause an additional iteration

c. EXECUTE - initiate a new OD based on the current control parameters

Another feature of the SB mode of the ODE shall be the capability to use the time of either the first or the last valid observation of the data set as the output time for the final results. The ODE always produces the solution at the time of the first valid observation of the data set. The SB mode shall, however, provide the capability to propagate the results (a priori state vector, output, and covariance) to the time of the last valid observation of the data set. This propagated solution shall then be stored in the SBHT upon receipt of the SB ACCEPT command.

9.3.1 SB EXECUTE

The purpose of the SB EXECUTE entry to the ODE shall be the initiation and control of an OD, based on multiple batches of ground-based navigation tracking data as a single data set, and using a variable length solution vector. The following is a general outline of the required functions of the SB.

a. Check input controls and initialize the control table.

b. Set the temporary covariance flag if the temporary covariance override submode is requested.

c. If the first and last batch ID's are properly input, proceed with the SB logic; otherwise, send a message to the user and return control to the system.

d. Use the DFCP to locate the batches requested and to determine data needed for execution (sec. 9.3.1.2).

e. If any of the following errors are detected, set an appropriate error message and return to the system.

(1) DFCP errors

(2) Any two vent time intervals in the solution vector overlap

f. Assign an ID for this SB solution.

g. Use the OD function to perform the OD as defined.

h. If the user requested the time of the last valid observation of the data set (t_ℓ) as output time

(1) Obtain the state transition matrix from anchor time to output time from the CP.

(2) Save the current estimate of the state vector (at time of first observation)

(3) Set the current solution equal to the state vector at t_ℓ

(4) Use the FFP to propagate the a priori state vector to t_ℓ and store as the a priori state vector

(5) Use the CMP to propagate the "fit-world" covariance matrix to t_ℓ.

i. Compute desired parameters for display.

j. Return control to the system.

The following sections give further details to the SB mode requirements.

9.3.1.1 SB Initialization Verification

The SBCT (sec. 14.0) for the specified DC link shall be used to initialize the parameters required for the OD. The following tests shall be performed prior to proceeding with any further processing.

a. Has the DC link been initialized?

b. Has a state vector source been identified for the input state vector?

c. Has an input covariance matrix/mode (sec. 7.0) been identified?

If the answer to any of the above questions is no, the ODE shall terminate further processing, display the appropriate error message, and return control to the system.

9.3.1.2 SB Data Set

The data set for the SB processing shall be defined as the string of consecutive batches of low-speed navigation tracking data, which have not been explicitly excluded, starting with the user-specified first batch and ending with the user-specified last batch. The exclusions are indicated by the SB format exclusion flags in the VDT header (sec. 4.1.1) and the SB exclusion flag in the data batch header record (sec. 4.2.1). If either the first or last data batch is missing from the VDT, or if either one is excluded from SB solutions, an error message shall be set, and control returned to the system. Another fatal error shall be the occurence of nonzero delta-V maneuvers defined in the MPT during the time interval spanned by the data set. If this occurs, an error message shall be set and control returned to the system.

The ODE requires the following information concerning the data set.

a. For the ODE processing

   (1) Time of the first valid observation in the data set (batch time of first data batch)

   (2) Time of the last valid observation in the data set

   (3) List of all tracking and data relay satellite (TDRS) ID's found in the data set

   (4) Number of data batches in the data set

   (5) List of data batch ID's for the data set

b. To be transmitted to the differential correction module (via OD and CP)

   (1) Number of data batches in the data set

   (2) List of data batch ID's in the data set

   (3) List of batch times for the data set

   (4) Time of the first and last valid observations for the data set

c. For display

   (1) List of batches excluded from data set because of tracking type exclusion

   (2) List of batches excluded from data set because of batch header record exclusion flag

9.3.1.3 SB Solution Vector/A Priori State Vector

MED inputs shall define the contents of the SB mode solution vector. The solution vector shall be constructed as defined in section 5.0. The SB mode shall allow 6 to 15 elements in the solution vector. Six elements of Cartesian mean of 1950 position and velocity shall always be present. The remaining nine elements are any allowed combination of the dynamic parameters and data biases.

The user shall specify (by MED) an input state vector ID and a priori values for solution vector elements other than position and velocity. These data shall be used to construct the a priori state vector as described in section 6.0.

9.3.2 SB ACCEPT

The SB ACCEPT entry in the ODE shall provide the user with the capability to store the results of the current SB solution for the identified DC link into the appropriate SBHT. Section 14.0 defines the parameters required for the SBHT.

If the SB decision waiting flag is not set to "YES", an error message shall be sent to the user, and control returned to the system. Otherwise, the solution shall be stored in the SBHT, the SB decision waiting flag be set to "NO," and control returned to the system.

9.3.3 SB FORCE

The purpose of the SB FORCE entry is to force an additional iteration in the CP called by the OD. No change in the data set nor the SB control parameters shall occur. When the SB FORCE entry is requested by the user for a specific DC link, the SB logic shall

a. Test the SB decision waiting flag and return to the system with the appropriate error message if the flag is not set to "YES".

b. If the requested output time is that of the last valid data point, restore the current estimate of the state vector and the anchor time to the values at the time of the first valid observation of the data set.

c. Use the OD function to perform one additional pass through the OD procedures.

d. If no errors are encountered, and the requested output is the time of the last valid observation, save the current estimate of the state vector (at first observation time) and store the state vector and covariance at the last observation time into the current solution region of the control table.

e. Compute display parameters and return control to the system.

10.0 OD FUNCTION

The OD function consists of that logic sequence which is common to the three DC modes. The purpose of the OD is to verify that the solution has been defined and to use the FFP, CMP, CP, DFCP, and RCP to accomplish the actual OD.

If the requesting command is a "FORCE" or if the CP flag is "YES" (indicating a postedit call to the CP), or the edit loop counter is not equal to zero, the logic shall be routed directly to the CP; otherwise, the following tests shall be performed.

a. Is the input state vector ID defined?

b. Is the input covariance matrix ID and/or mode defined?

c. Have the solution vector size and contents been defined?

If the answer to any of these tests is "NO", an error mode flag shall be set, and control returned to the requesting function; otherwise, processing shall continue with the following.

a. Locate input state vector and time for the target vehicle and move it to the control table.

b. Add a user-specified increment of semimajor axis to the state vector (sec. 6.3.1), and test the magnitude of the position vector for validity. If invalid, set the appropriate error mode flag and message, and return control to the requesting function. The semimajor axis increment is set to zero after use.

c. If the input state vector contains vent or drag multiplier information, it shall be transmitted to the FFP. If either type of dynamic parameters is available, but the integrator options are not set to use the information, the OD shall send a warning message to the user and continue processing using the specified integrator options.

d. If the state vector reference time is not equal to the desired anchor time, use the FFP to move the state vector from its reference time to the anchor time using the specified force model options. If an integration error occurs, a descriptive flag shall be returned to the requesting functions and control returned to the system.

e. If the a priori state vector is to contain more than six elements, the remaining elements shall be filled from the input portion of the control table.

f. A test shall be performed to determine which, if any, TDRS ephemerides are required. If any are needed that do not exist, the FFP shall be invoked to generate them. A minimum of nine points, spaced at a maximum interval of one beta step, where a beta step equals 0.0625 $ER^{-1/2}$, are required for interpolation. If an integration error occurs, the appropriate flags shall be set, and control returned to the system.

g. If the temporary covariance flag is set to 1, use the temporary covariance specified; otherwise, use the covariance specified by the SBCT.

h. If the use of an a priori covariance matrix has been specified (options SS2, SS3, SS4, or CMi), the matrix shall be located. The CMP shall then be used to transform the state portion of the matrix, propagate that portion to the anchor time, and fill in the remainder (if any) of the covariance matrix. It shall then be moved into the control table. The matrix shall be multiplied by the factor K^n (where n is the number of times the KGAMMA PBI was depressed), inverted, and the result stored in the appropriate control table. The method utilized to invert the covariance matrix shall compensate for ill-conditioning and shall treat zero-diagonal elements as signifying no information rather than perfect information. If, however, the SS1 option was specified by the user, then both the slot for the covariance matrix and the slot for its inverse in the control table shall be zeroed out. Any errors encountered in covariance matrix manipulation shall cause a message to be sent to the user and control to be returned to the requesting function.

i. The CP shall be used to obtain an updated estimate for the state vector. If the OD has been invoked for the first pass of an edit run, the CP shall be omitted. An error return from the CP shall cause the return of control to the system.

j. Using the current estimate of the state vector at anchor time (including dynamic parameters), use the FFP to generate a target-vehicle ephemeris that spans the time interval for the entire data set. The state vector at the time of the last observation shall then be stored in the control table. An error in integration shall cause the appropriate error mode to be set, and control returned to the calling function.

k. The statistics of observations processed for each observation type shall be initialized to zero.

l. If the first batch of data is not available, the DFCP shall be called to retrieve it for use by the RCP. Every succeeding batch required in the solution shall be retrieved by the DFCP.

m. The RCP shall be used to compute residuals and associated statistics for each batch of data, and the total number of observations for each data type shall be accumulated.

n. If the total number of observations used is equal to zero, an error code and message shall be set for return to the calling function.

o. Control shall then be passed back to the requesting function.

11.0 EDIT FUNCTION

The EDIT function shall provide control of the data editing for the OD process. EDIT shall use the DEP to identify and edit observation data whose residuals lie outside the general pattern of the data residuals. DFCP shall be used to store the data batch, in its final edited status, into the VDT.

11.1 DETAILED EDIT FUNCTION REQUIREMENTS

In the editing procedure, residuals shall be computed in the OD function (sec. 10.0) and passed along with the data batch to the EDIT function for processing by the DEP. The following shall be performed:

a. Use the DEP to perform the actual edit.

(1) If an edit problem is encountered in the DEP, EDIT shall set an appropriate error mode, message flags, and setup to terminate the editing process.

b. Control the number of edit loops.

(1) If the DEP changed the edit status of at least one point in the data batch, and the user-specified maximum number of edit loops has not been performed, control shall be returned to the requesting function for an additional edit loop.

(2) If the maximum number of edit loops has been performed, an appropriate error mode and message shall be set, and control shall be returned to the requesting function for a final pass through the OD.

(3) If the DEP did not change the edit status of any points in the batch, and more than one pass through the edit loop has been performed, the edit process is terminated. If this is the first edit loop, control shall be returned to the requesting function for a final pass through the OD.

c. Ensure that the final OD is based on the data batch in its final edited status.

d. Use the DFCP to write the data batch, in its final edited status, into the VDT.

(1) Set the edit indicator in the batch header record.

(2) Store the number of edited points and an "EDITED" flag into the batch header record.

12.0 DISPLAY COMPUTATIONS

The ODE shall compute parameters to be displayed as an aid to the user evaluation of the converged (final estimate) state vector and its consistency with the low-speed navigation tracking data.

12.1 STATE VECTOR

Certain parameters shall be computed from the final estimate of the state vector (at output time). These include the magnitudes of the position and velocity, the classical orbital elements, apogee and perigee height, and their changes from the a priori. The computations are discussed in volume XIV.

12.2 DATA STATISTICS

The ODE shall use the residual computations processor (RCP) and batch header record information to compute the observation residual statistics for each observation (angle 1, angle 2, range, and Doppler). The RCP shall compute the mean (μ), the standard deviation (σ), and shall count the number of accepted data points n of each observation type for one batch at a time. The total number of each observation and the number of edited observations shall be available from the batch header record. Therefore, all ODE calculations shall be trivial for single batch solutions.

SB solutions shall require that statistics be accumulated across several batches for each observation type. Using the subscript "i" to denote the result from an individual batch, compute

$$N = \sum_i n_i$$ total number of an observation type accepted

$$\mu = \frac{1}{N} \sum_i n_i \mu_i$$ mean of an observation type

$$\sigma = \left[\frac{1}{N-1} \left(\sum_i n_i \cdot (\mathrm{RMS})^2_i - N\mu^2 \right) \right]^{1/2}$$ standard deviation of an observation type

Where $(\mathrm{RMS})_i$ is the root mean square from the RCP of the residuals for a given observation type in batch "i."

The total number of valid observations and edited observations shall be accumulated for each observation type. The total number of each observation type excluded shall be computed by subtracting the number accepted from the total number of valid observations.

13.0 SOLUTION CONTROL TABLES

A solution control table is maintained for each ODE mode (BB, SB, and DCE) in each of the six possible DC links (ORB 1, 2, 3, PAY 1, 2, 3). The contents of each of the 18 tables is as follows:

a. DC LINK ID - identifies which DC link is associated with the table

b. OD MODE ID - identifies the ODE mode (BB, SB, or DCE) for which the table applies

c. OD activation ID - indicates if the mode in (b) is "activated" or "deactivated"

d. Decision waiting flag - indicates that a user decision is required to either accept or reject the current solution.

e. Solution request flag - indicates how ODE was queued to perform a solution. The possible values of this flag are: execute, rechain, BB initial, DCE initial, accept, reject, or force.

f. Data set specification - all information required to define the data set to be processed

(1) Initial batch ID
(2) Final batch ID
(3) Batch and format exclusion flags (for display)
(4) Measurement-type exclusion flags
(5) Start time of data arc
(6) Stop time of data arc

g. Solution vector ID - information that defines each element of the solution vector

(1) Vent (I) - I = 1, 2, 3

(a) Start time for vent (I)
(b) Stop time for vent (I)
(c) Force components for vent (I), body axes
(d) Solution vector flag for vent (I)

(2) Drag multiplier

(a) Value of drag multiplier
(b) Constant area or attitude-dependent option
(c) Solution vector flag

(3) Bias (I) - I = 1,...,9 (I = 1-3 are two-way/three-way and I = 4-9 are hybrid). For each I, the following are included: solution vector flag and bias value

h. Input state ID - identifies the input M50 Cartesian state

i. Output time - epoch of the desired solution state, and an indicator specifying whether this epoch is the start time or stop time of the data arc.

j. A priori covariance - all data required to identify the a priori covariance matrix

(1) Covariance mode (SS1, SS2, SS3, SS4, or CM1-4)
(2) Covariance ID (if SS4)
(3) Parameter elements ID (none, BCOV, or SnCOV)
(4) Covariance multiplier information
K = value of KGAMMA multiplier
n = number of times the KGAMMA PBI is depressed prior to solution

k. Solve mode = flag that has the value

    (1) 6 = solution vector (M50 Cartesian state only)
    (2) 9 = solution vector (M50 Cartesian state + vent (1))
    (3) -1 = solution vector (M50 Cartesian state + elements identified in "solution vector ID")

l. TDRS vector ID's - for each TDRS (E, S, W)

m. Edit flag - indicates whether or not the automatic editing function is used in the BB mode

n. Minimum elevation/altitude - three test-limit parameters

    (1) MINEL = minimum allowed elevation for ground-direct measurements
    (2) RMNEL = minimum allowed elevation for ground-to-TDRS RF link
    (3) MINCA = minimum allowed altitude for vehicle-to-TDRS RF link

o. Integration options - flags that indicate the following:

    (1) M = include burns from MPT
    (2) V = include vents
    (3) A or D = include "attitude dependent" or "constant area" drag

p. ODP control parameters - Control parameter values

    (1) JMAX = maximum number of iterations
    (2) Maximum edit loops
    (3) KMAX = maximum divergent iterations
    (4) $\bar{E}$ = convergence test parameters

        (a) CR - position elements
        (b) CVEL - velocity elements
        (c) CVENT - vent force components
        (d) CDRAG - drag multiplier
        (e) DBIAS - Doppler biases

    (5) Maximum allowed changes for each of the above. These are used in DCE test only.

q. DELTA A - semimajor axis increment to be added to input state

r. CURRENT SOLUTION information - input/output data that completely summarizes the OD solution

    (1) Solution ID
    (2) Input vector - M50 Cartesian state and epoch that is to be propagated to anchor time
    (3) Input covariance ID
    (4) A priori vector

(a) Time
(b) M50 Cartesian state
(c) Vent force components and start/stop times
(d) Drag multiplier
(e) Measurement biases
(f) Type ID
(g) Forward and return relay ID

(5) A priori covariance - up to 15x15 matrix at anchor time
(6) KGAMMA degraded a priori covariance - above matrix multiplied by K^n
(7) Output solution vector (content format same as a priori vector)
(8) Output solution covariance
(9) Other input information

(a) Data file

(i) Initial batch ID
(ii) Final batch ID
(iii) Tracking-type exclusion flags (C-band, S-band, and relay)
(iv) Batch exclusion flags (and exclusion type)
(v) Data biases - applied to all data types in specified batch
(vi) Start time of data arc
(vii) Stop time of data arc
(viii) Length of data arc ($T_{stop} - T_{start}$)

(b) Input vector

(i) Vector ID
(ii) Delta A
(iii) TDRS vector ID

(c) Input covariance

(i) Matrix ID (for 6x6 partition)
(ii) Parameter elements ID (BCOV, SnCOV)
(iii) K = KGAMMA multiplier
(iv) n = number of applications of KGAMMA PBI

(10) Other output information

(a) Residual statistics (all data types)

(i) Number of valid data points (total)
(ii) Number of edited points
(iii) Number of excluded (unedited) points
(iv) Number of accepted points (net)
(v) Mean of accepted residuals
(vi) Standard deviation of accepted residuals

(b) Useful output vector elements

(i) Position magnitude
(ii) Inertial velocity magnitude
(iii) Classical elements

(c) Number of iterations through DCM

(d) Number of edit iterations through DEP

14.0 DC HISTORY TABLES

Three DC history tables are maintained for each vehicle (DC link). These tables contain up to 50 entries. The three classes of tables correspond to the ODE modes. The tables are called: BBHT, SBHT, and DCEHT. The contents of each of these tables are as follows:

a. Header record

(1) Vehicle ID (DC LINK ID)

(2) ODE mode (BB, SB, DCE)

b. Records (up to 50) containing DC solution data

(1) Solution ID

(2) Input vector

(a) t_E = epoch

(b) $\vec{X}_E$ = M50 Cartesian state at t_E

(3) Input covariance

(a) C (t_E) = 6x6 M50 Cartesian element covariance

(4) A priori vector

(a) t_A = anchor time

(b) $\vec{X}_A$ = M50 Cartesian state at t_A

(c) $F_V(J)$ = components (vehicle body coordinates) of J-th vent force (J = 1, 2, 3)

(d) $T_{on}(J)$, $T_{off}(J)$ = ON/OFF times of each vent (J = 1, 2, 3)

(e) k_D = drag multiplier

(f) Drag option (constant area or attitude dependent)

(g) b = (b_1, b_2, ---) Doppler biases (up to 9)

(h) For each bias, b_i

(i) Type ID = two-way/three-way or hybrid
(ii) Forward link relay ID = E, S, W
(iii) Return link relay ID = E, S, W

(5) A priori covariance

$\Lambda(t_A)$ ≡ covariance (up to 15x15) of input solution vector at anchor time

(6) Output vector - content format is identical to (4)

(7) Output solution covariance - content format is identical to (5)

(8) Other input information

(a) Data file

(i) Initial batch ID
(ii) Final batch ID
(iii) Tracking-type exclusion flags
(iv) Batch exclusion flags and exclusion type
(v) Data-type exclusion flags (each data type)
(vi) Data biases (for each data type) for each batch
(vii) Start time of data arc
(viii) Stop time of data arc
(ix) Length of data arc

(b) Input vector

(i) Vector ID
(ii) Delta A
(iii) TDRS vector ID

(c) Input covariance

(i) Covariance ID, [for $C(t_E)$]
(ii) Parameter elements ID (BCOV, SnCOV)
(iii) K = KGAMMA multiplier
(iv) n = number of KGAMMA PBI applications

(d) Low elevation/altitude limits

(i) MINEL = minimum elevation for ground direct
(ii) RMNEL = minimum elevation for ground TDRS
(iii) MINCA = minimum altitude for vehicle (TDRS LOS)

(e) Integrator force model options

(i) Flags that indicate the following:

(aa) M = include burns in MPT
(bb) V = include vents
(cc) A = include attitude-dependent drag
(dd) D = include constant area drag

(9) Other output information

(a) Residual statistics (all data types)

(i) Total number of valid data points
(ii) Number of edited data points
(iii) Number of excluded data points (unedited)
(iv) Number of accepted data points
(v) Mean of accepted residuals
(vi) Standard deviation of accepted residuals

(b) Useful output vector elements

(i) Position magnitude
(ii) Inertial velocity magnitude
(iii) Classical elements
(iv) Number of iterations through DCM
(v) Number of iterations through DEP

APPENDIX A

FLOW CHARTS

APPENDIX A FIGURES

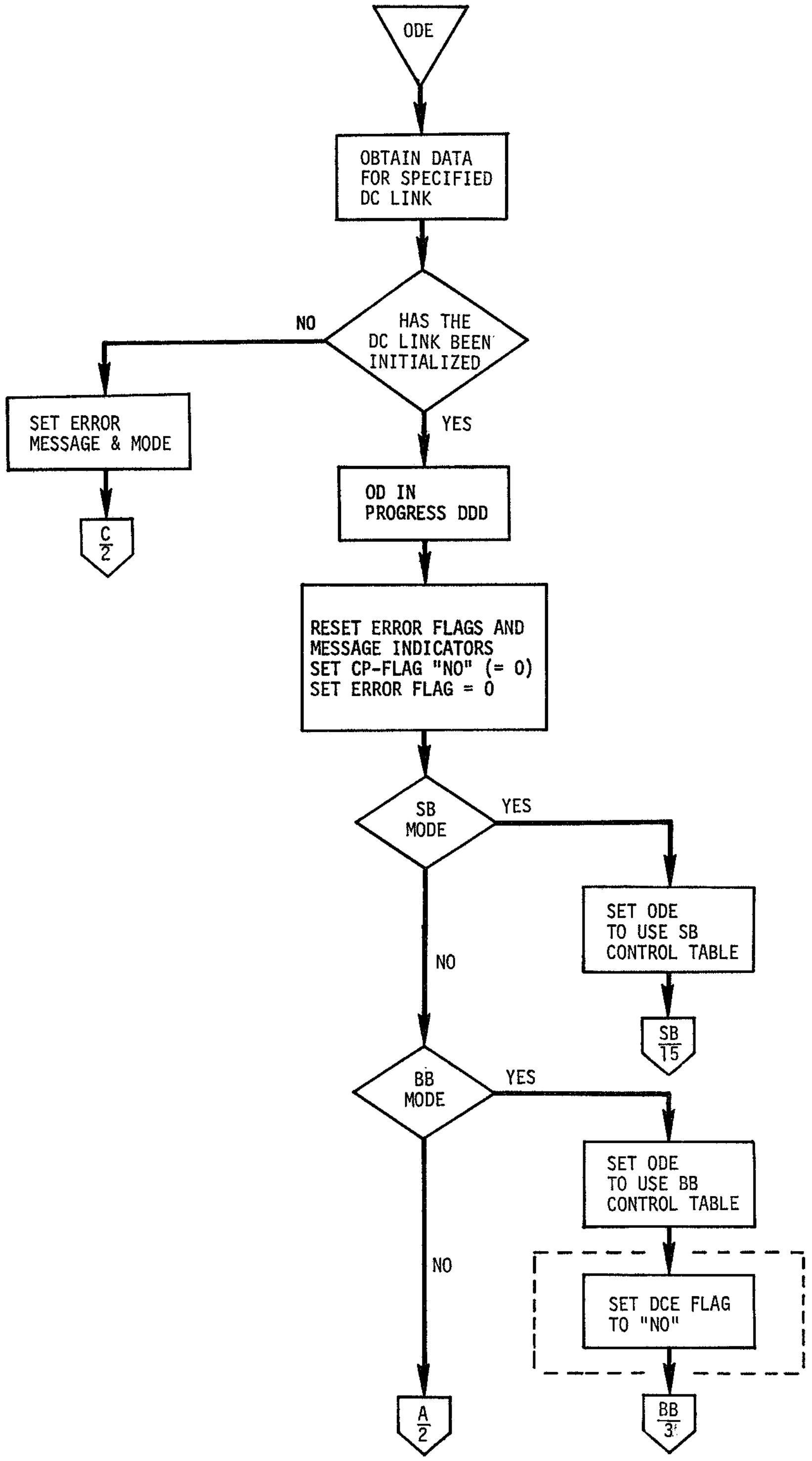

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Figure A-1.- Flow diagram for the orbit determination executive (ODE).

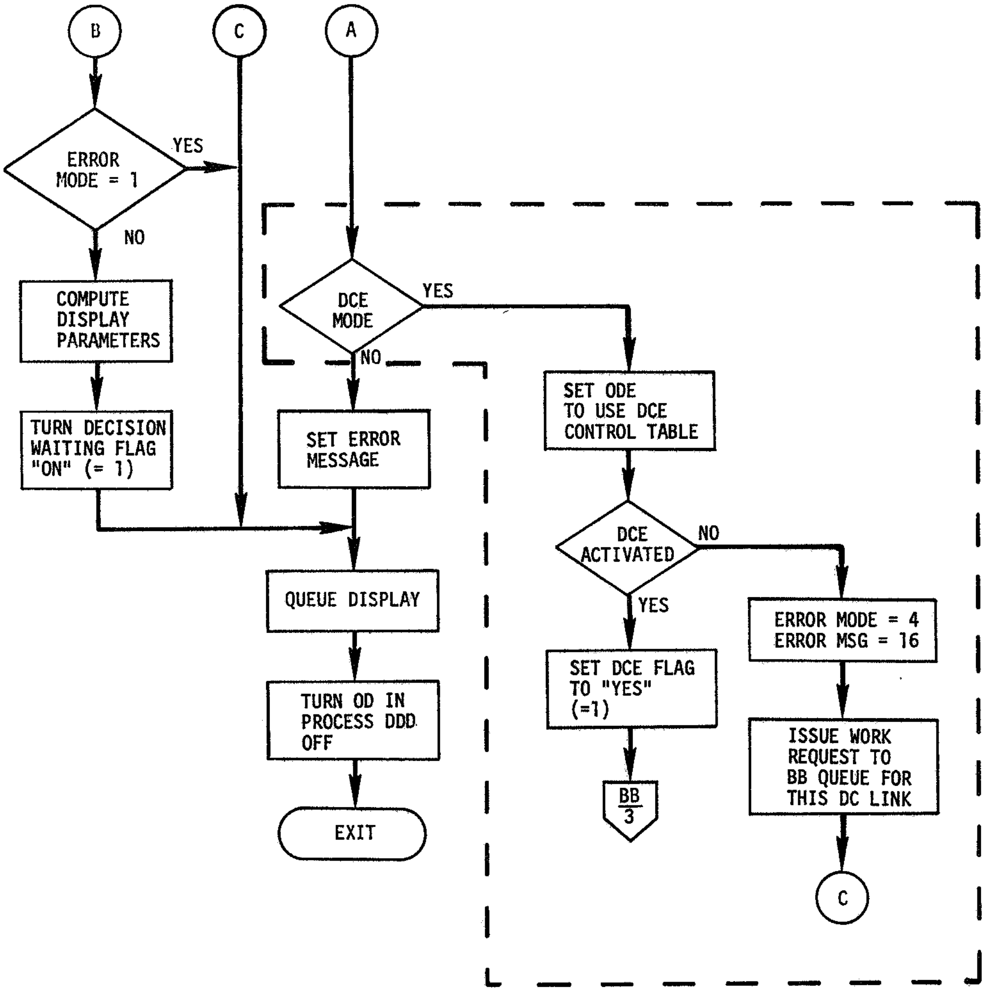

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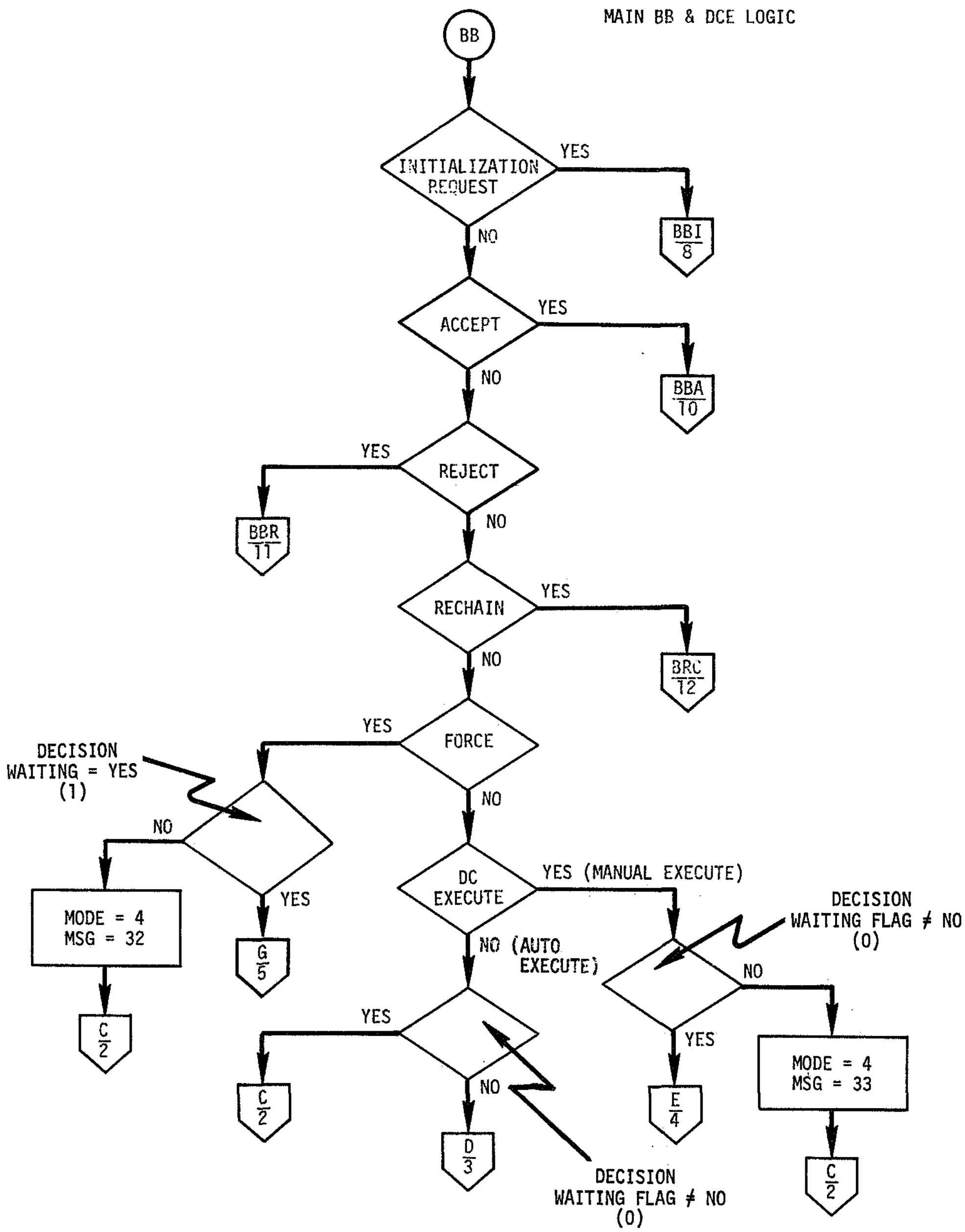
Figure A-1.- Continued.



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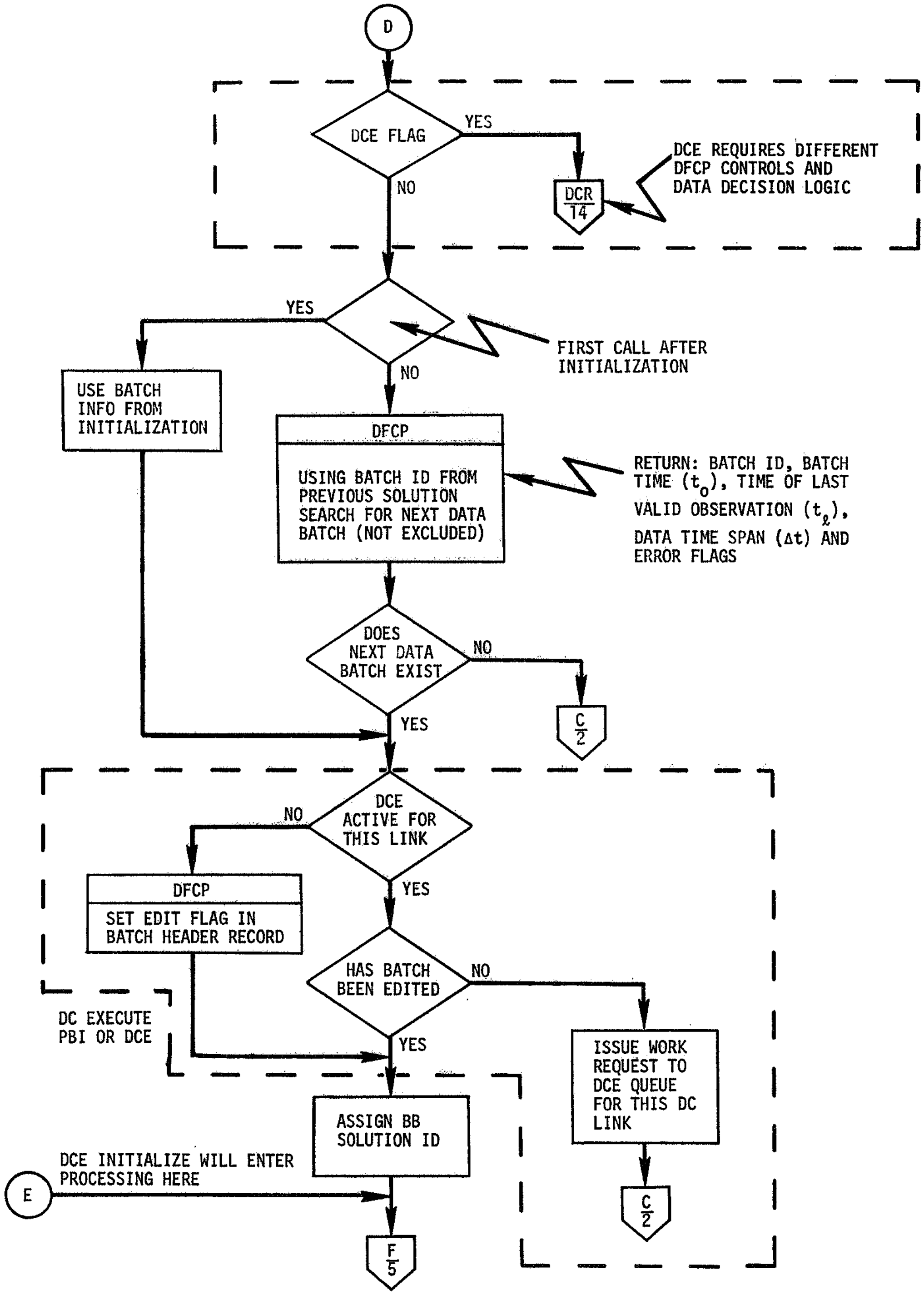

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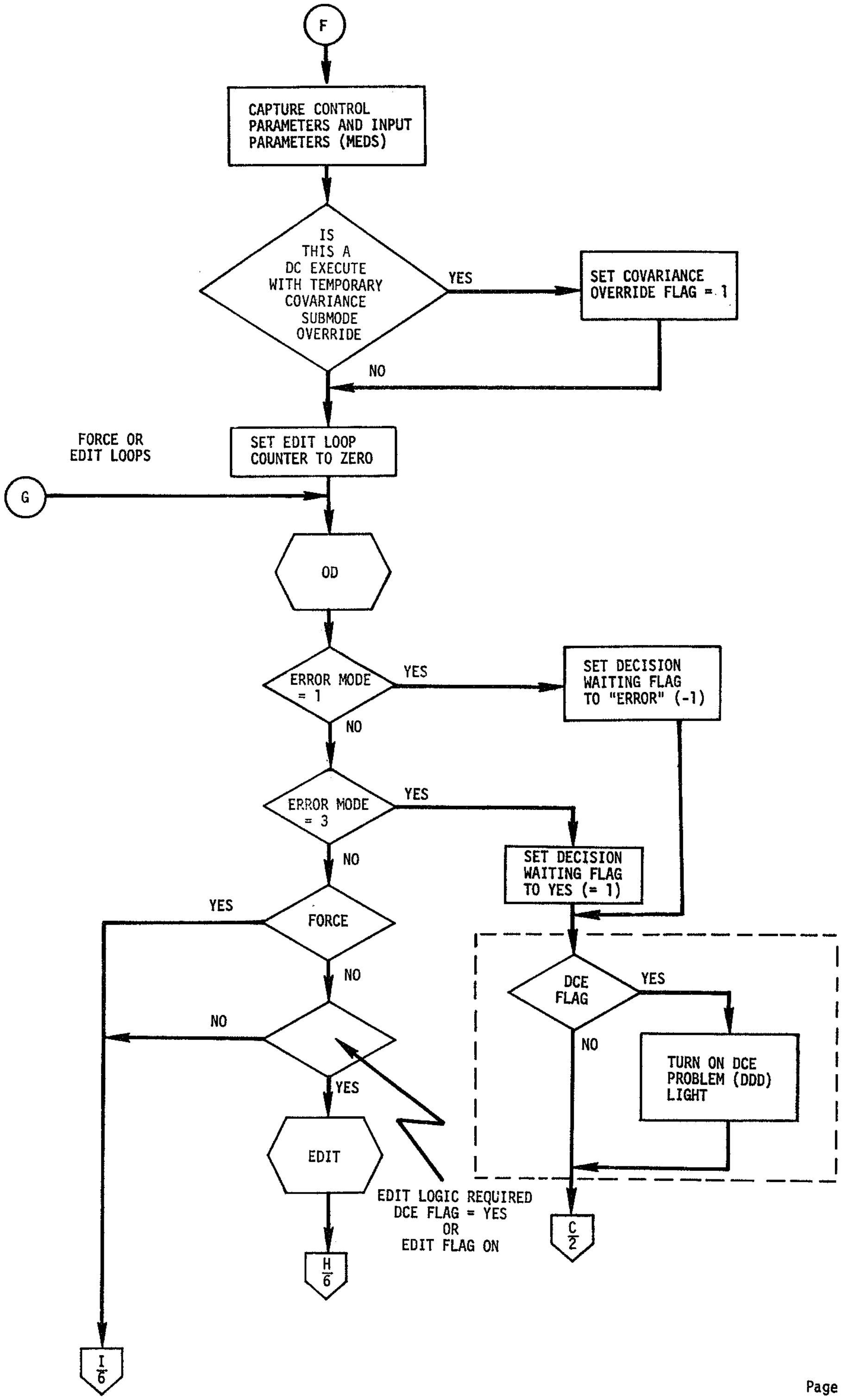

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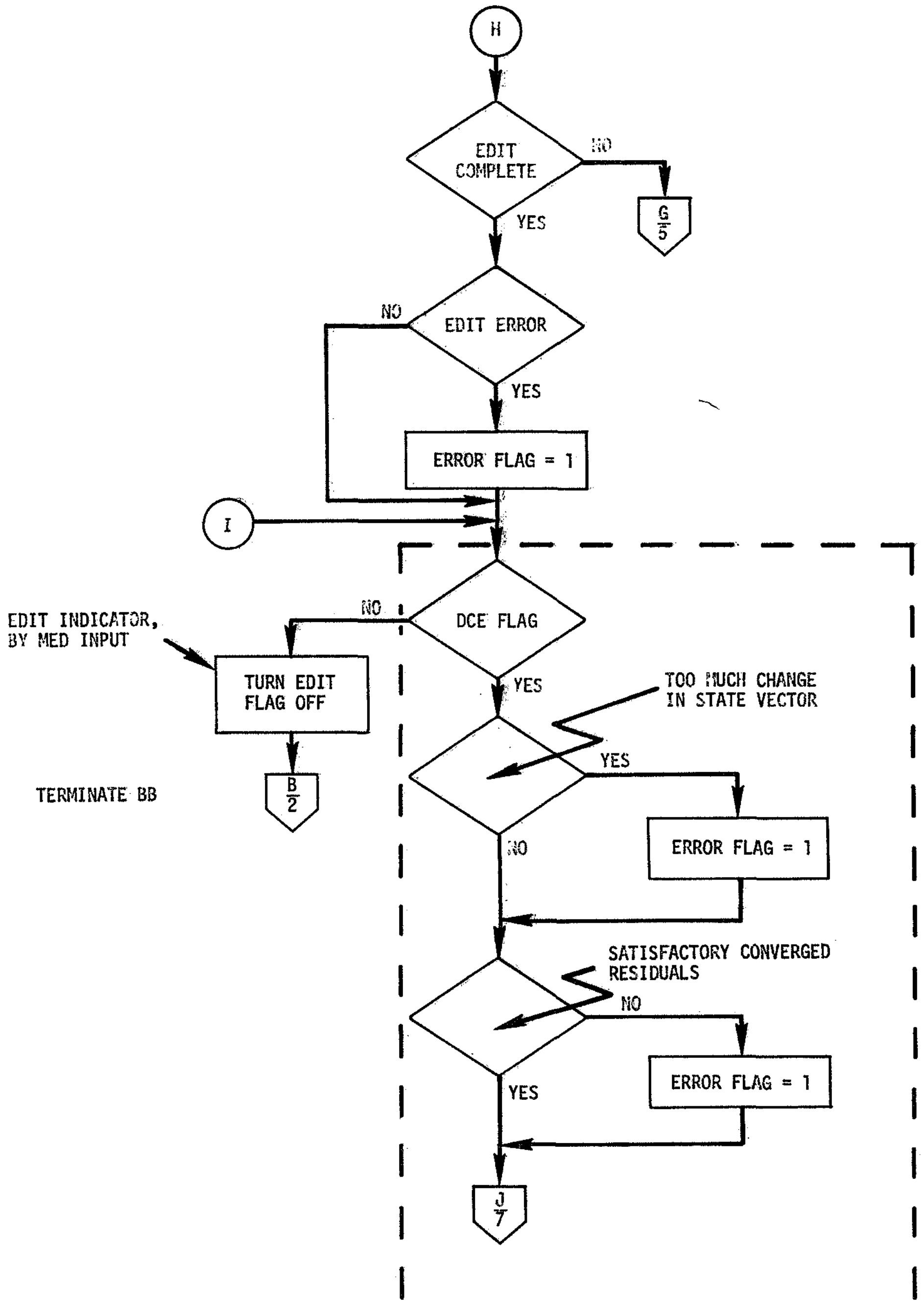

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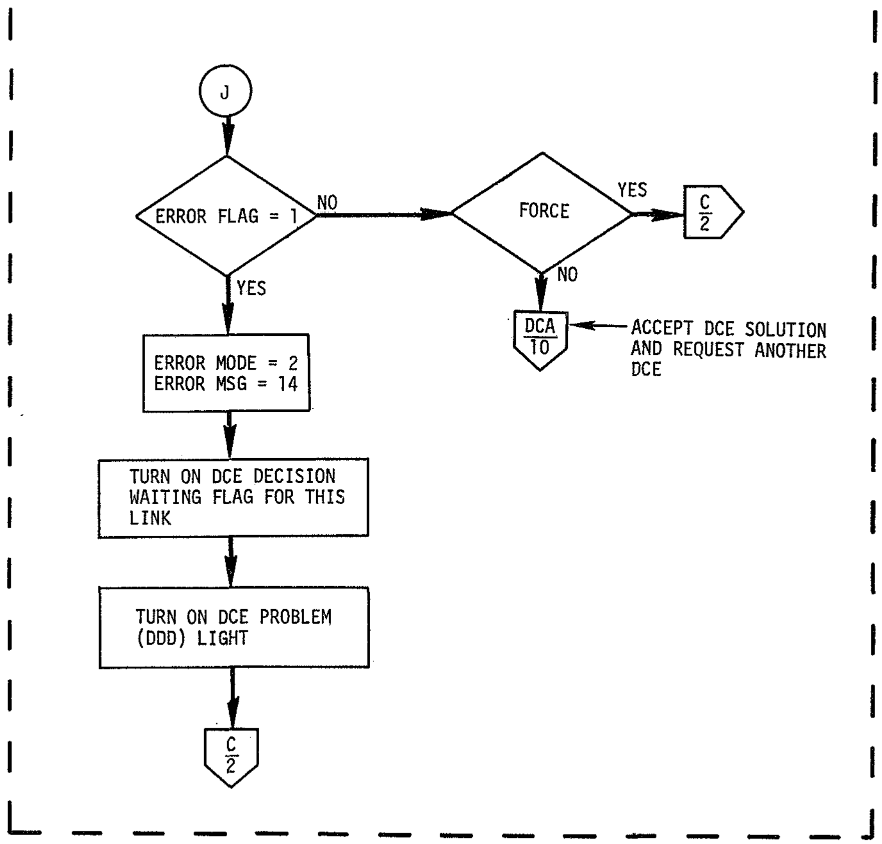

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Figure A-1.- Continued.

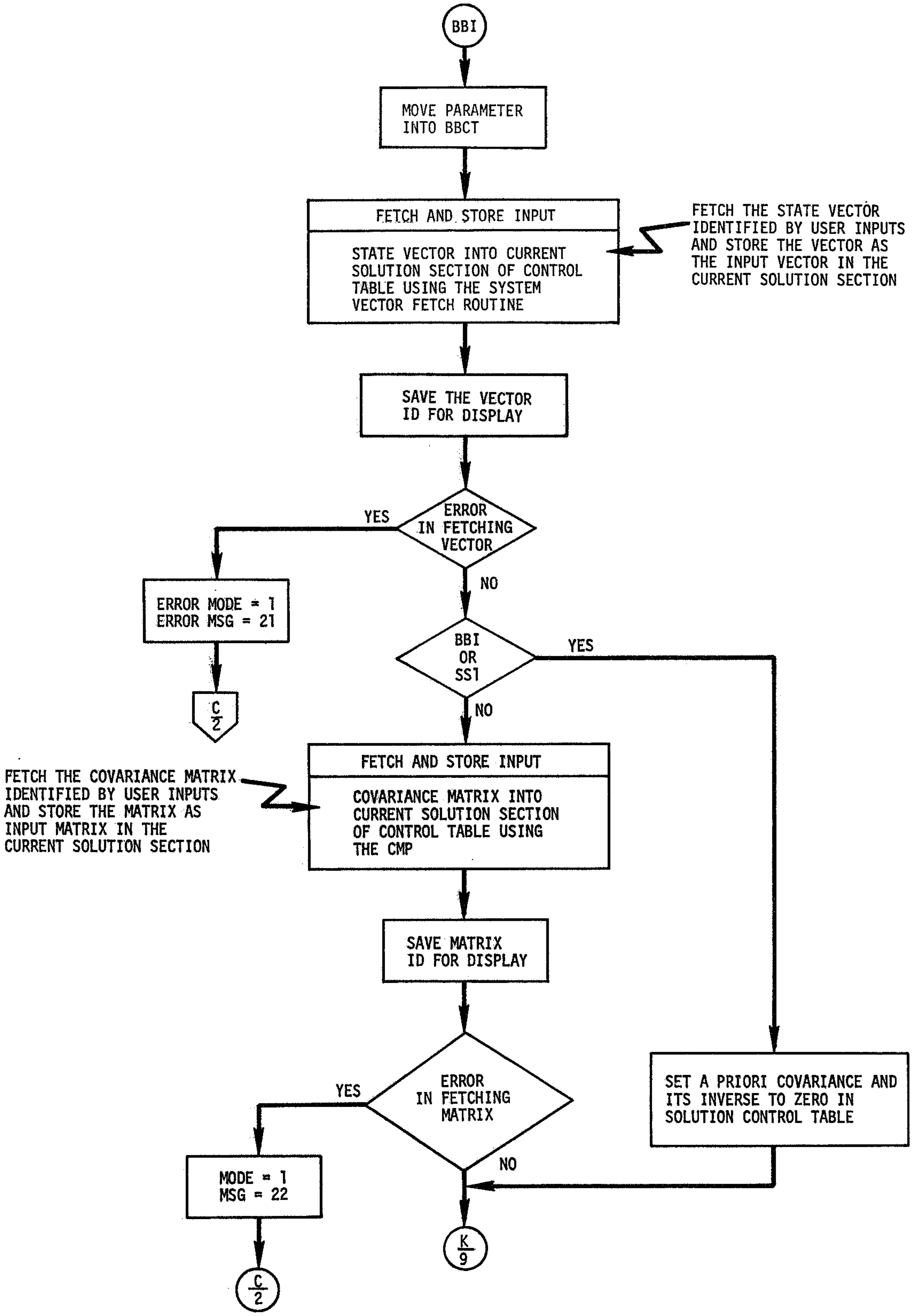

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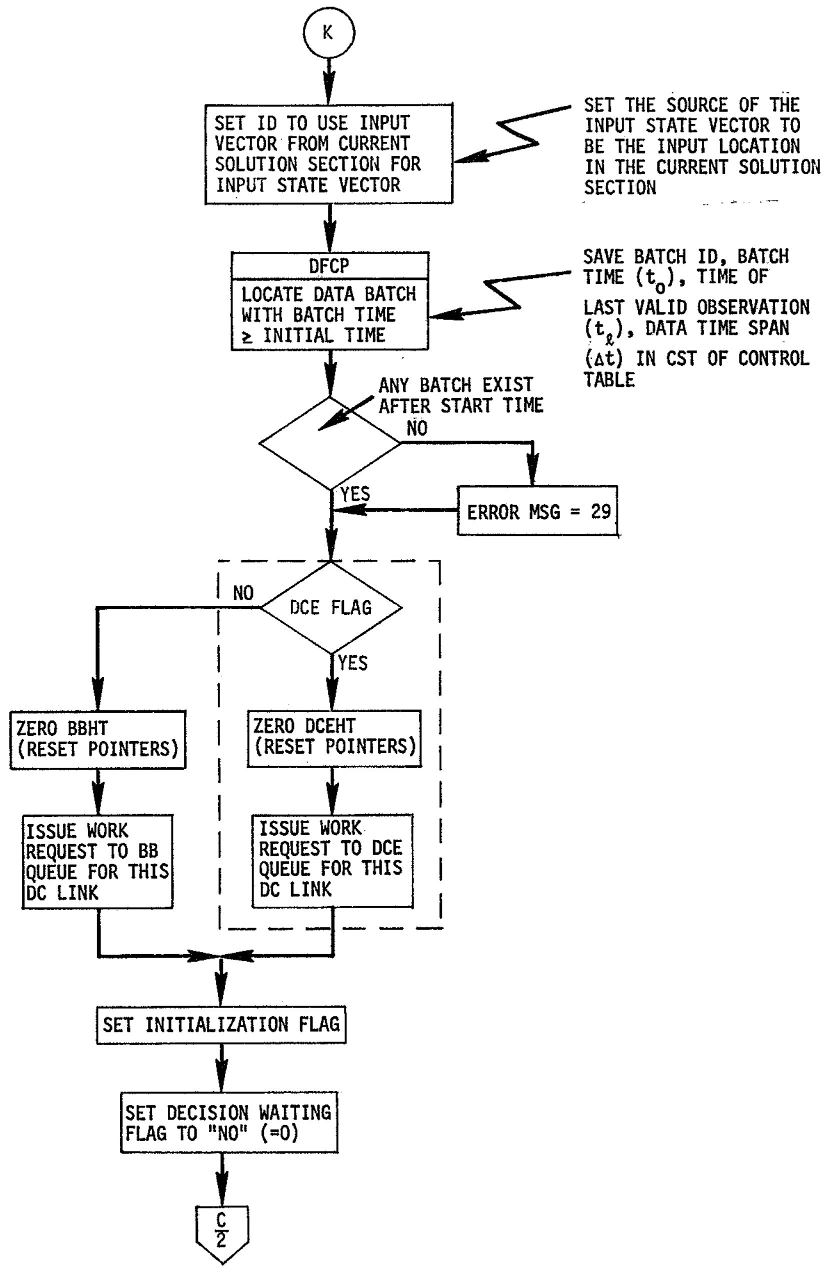
Figure A-1.- Continued.



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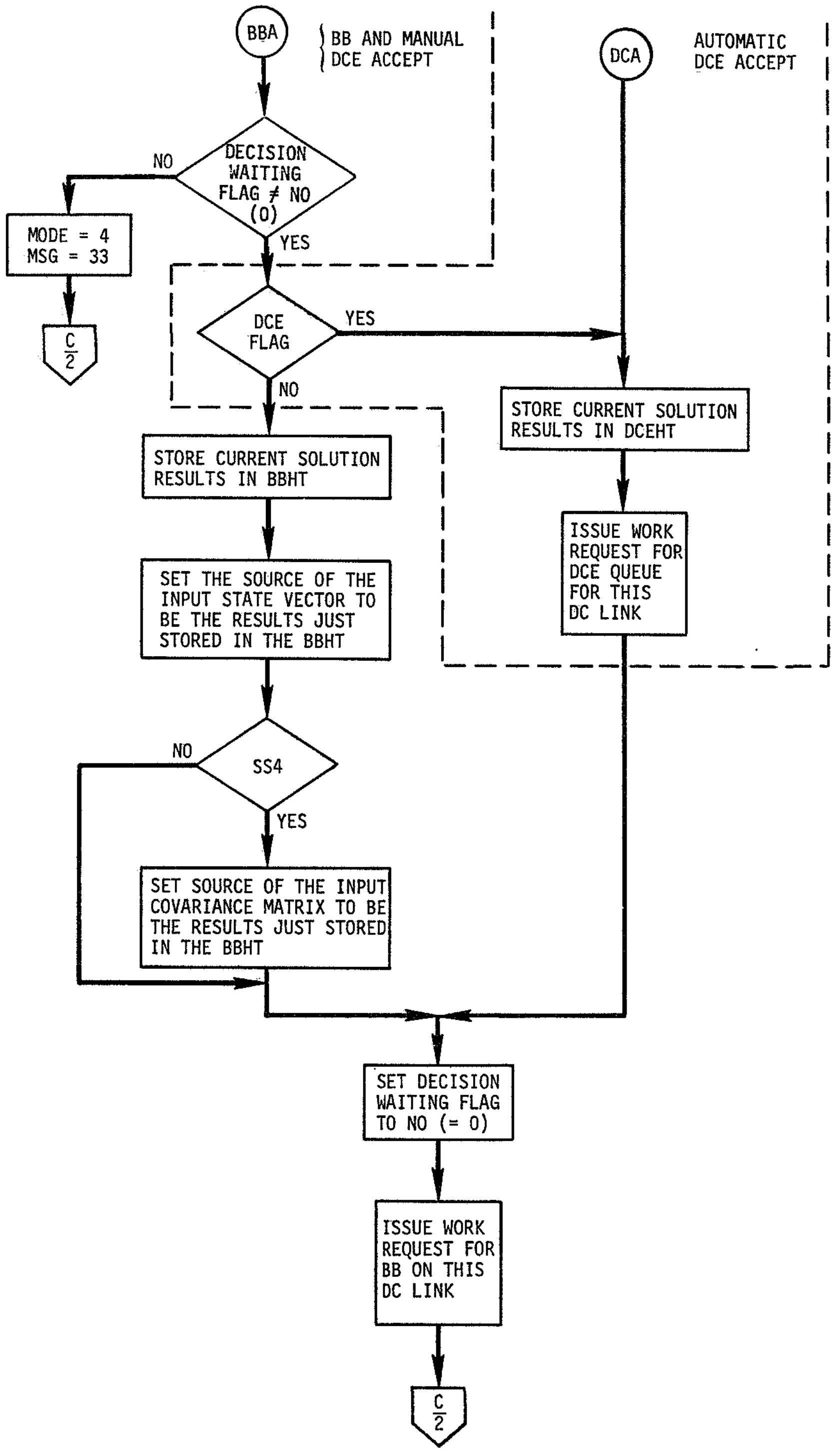

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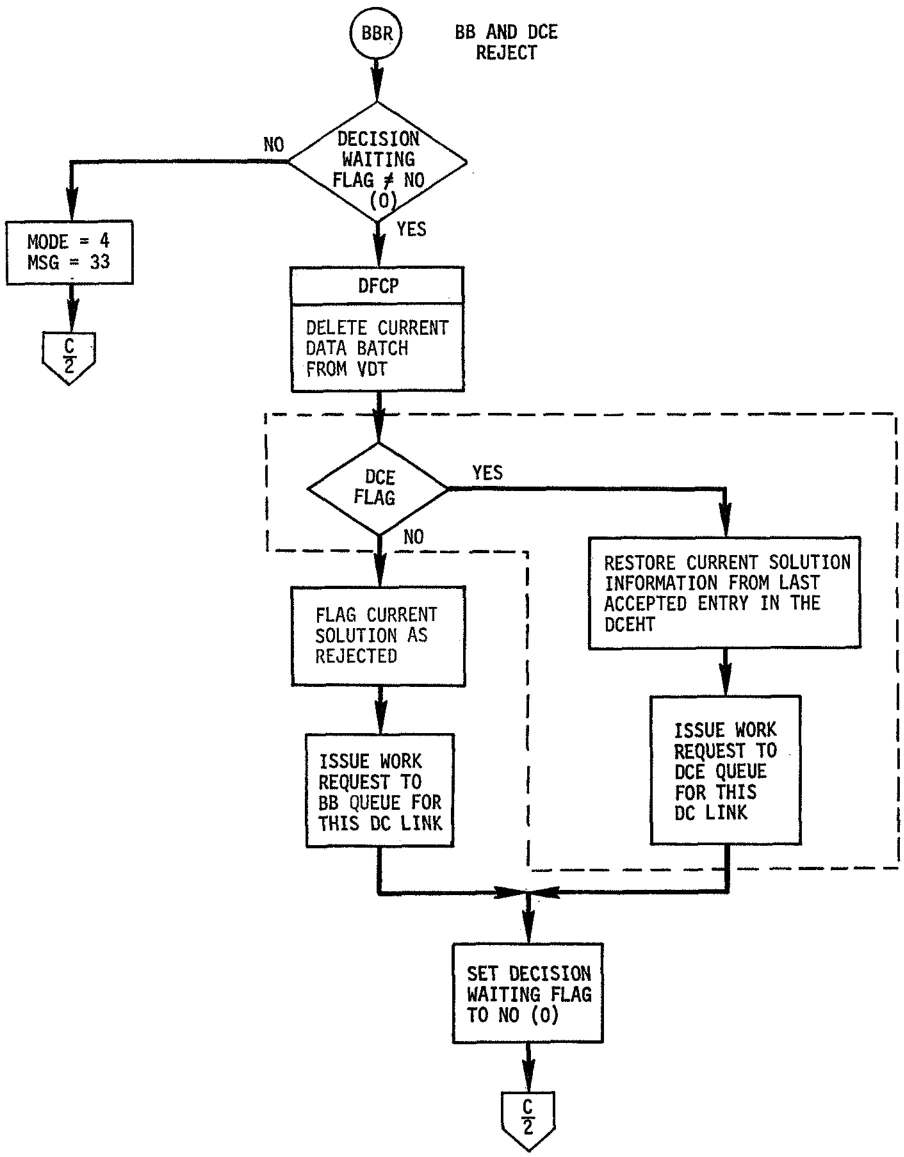

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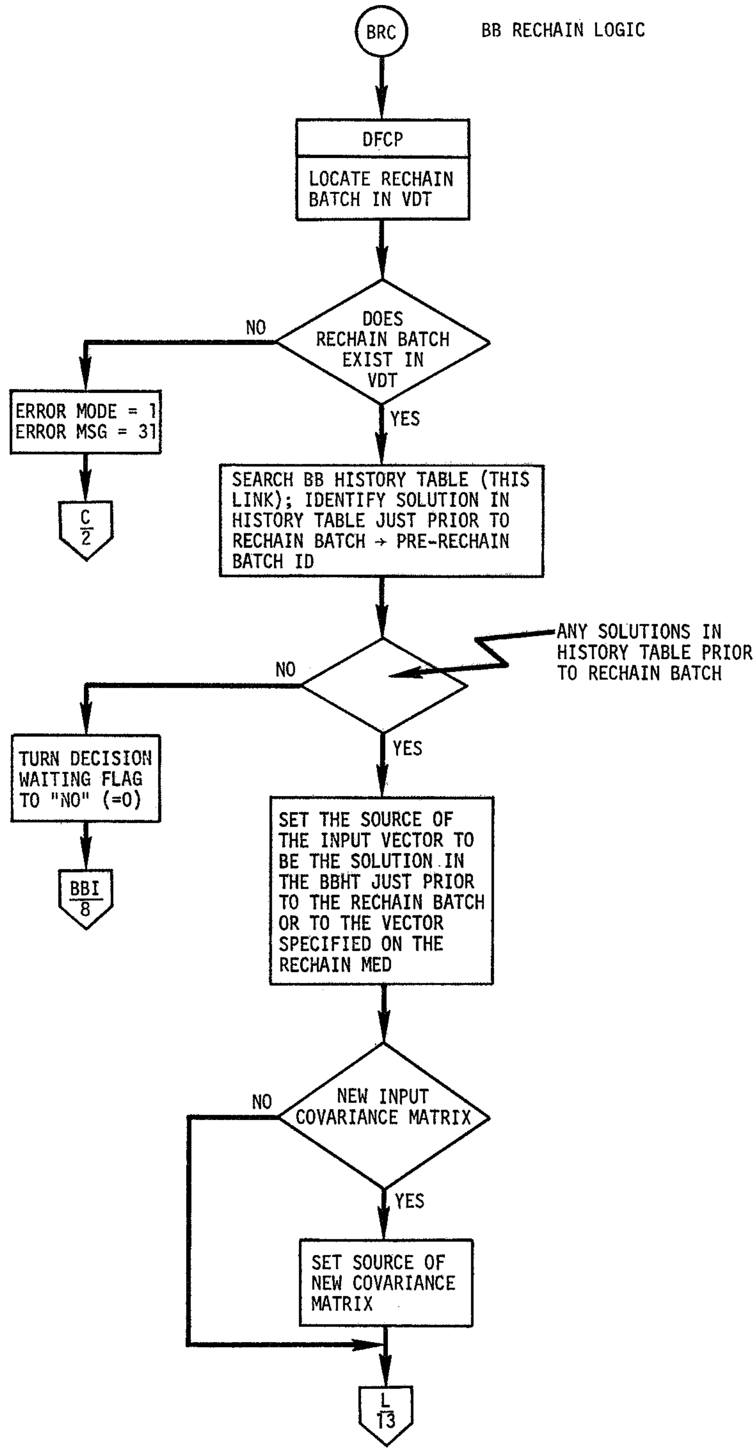

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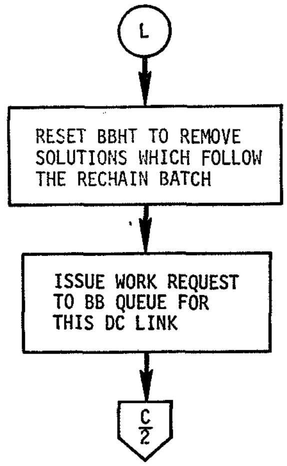

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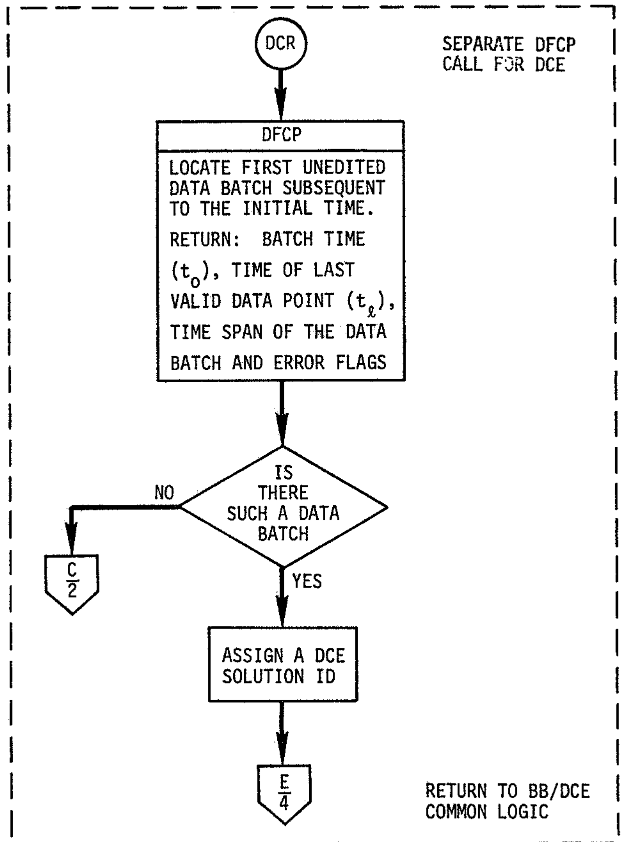

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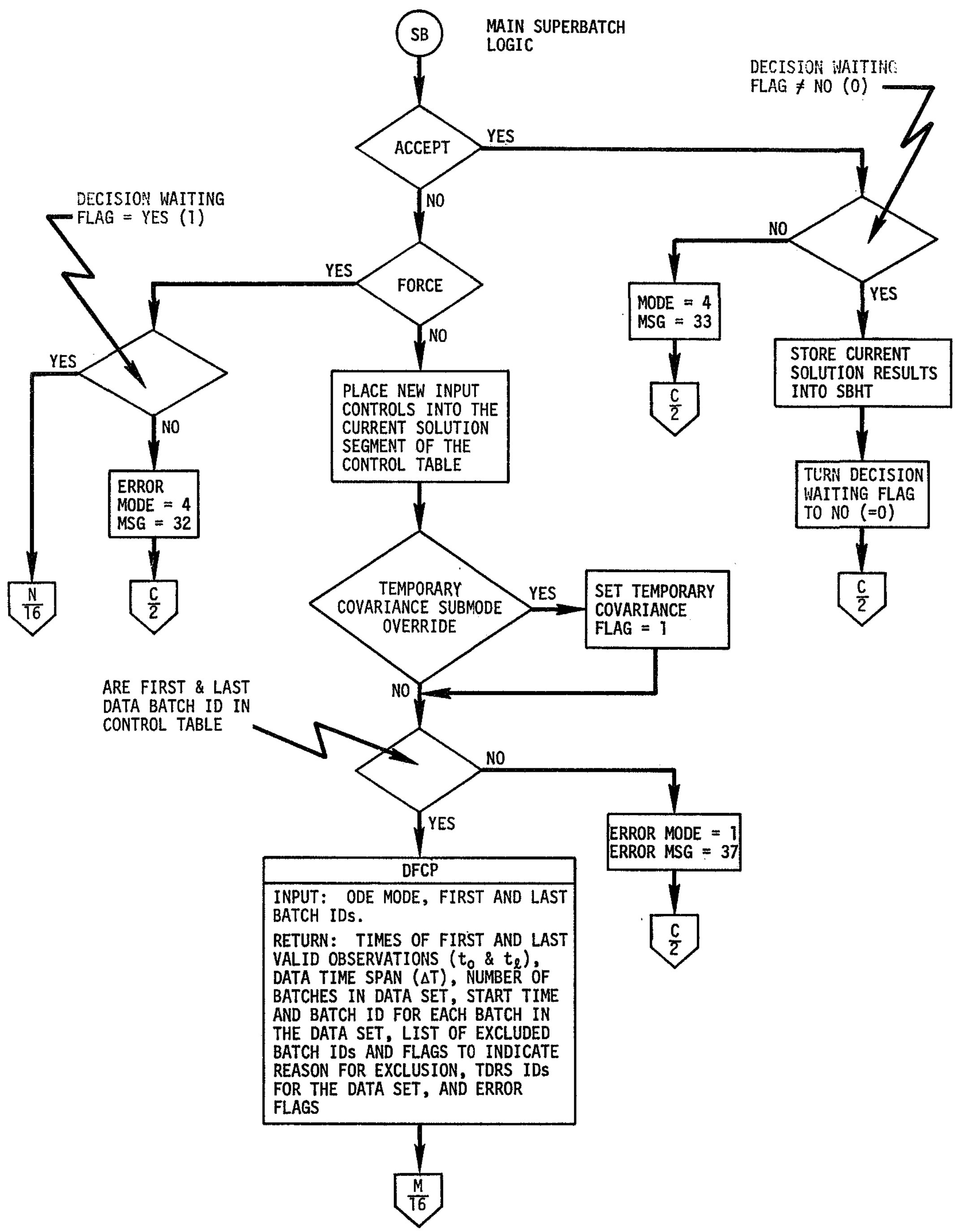

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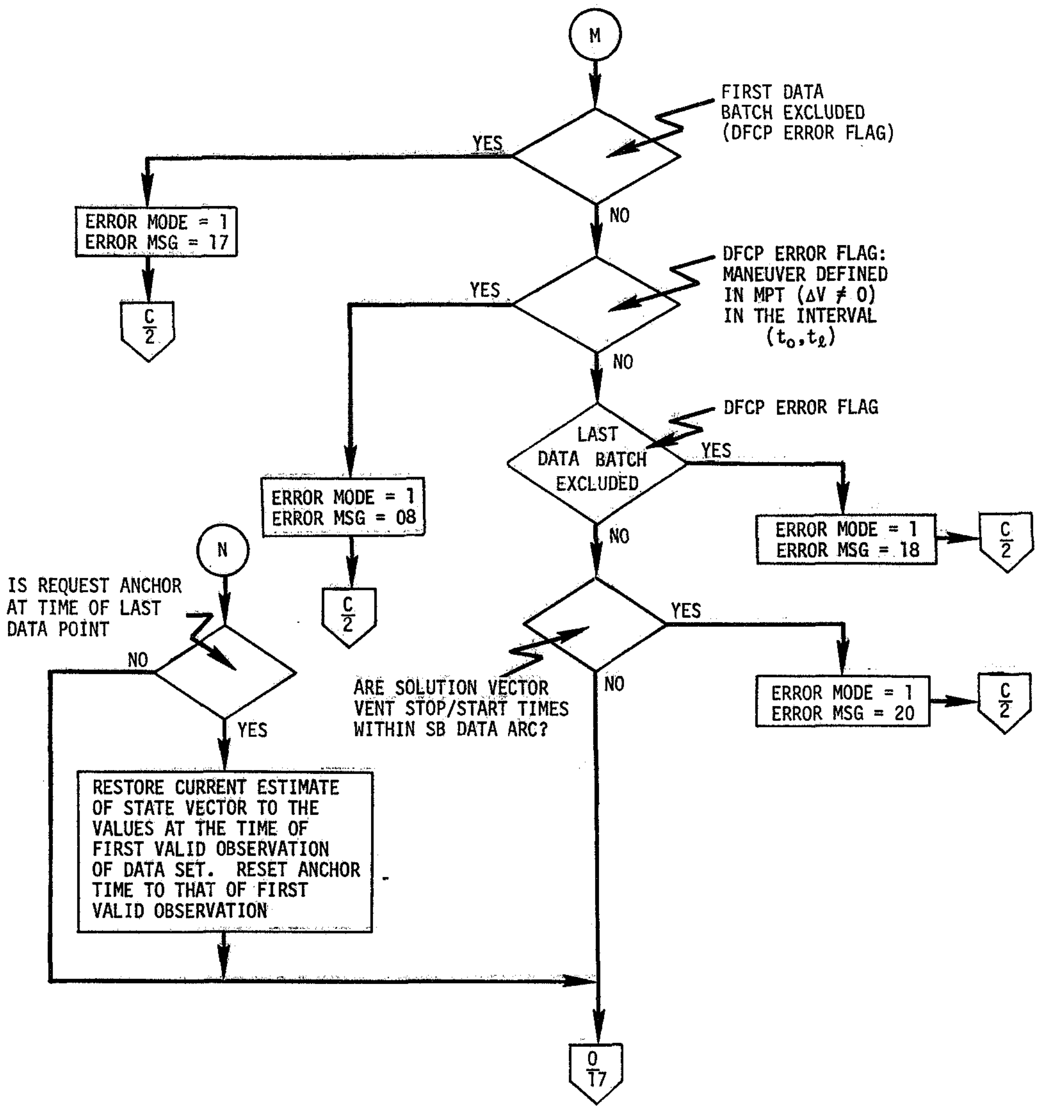

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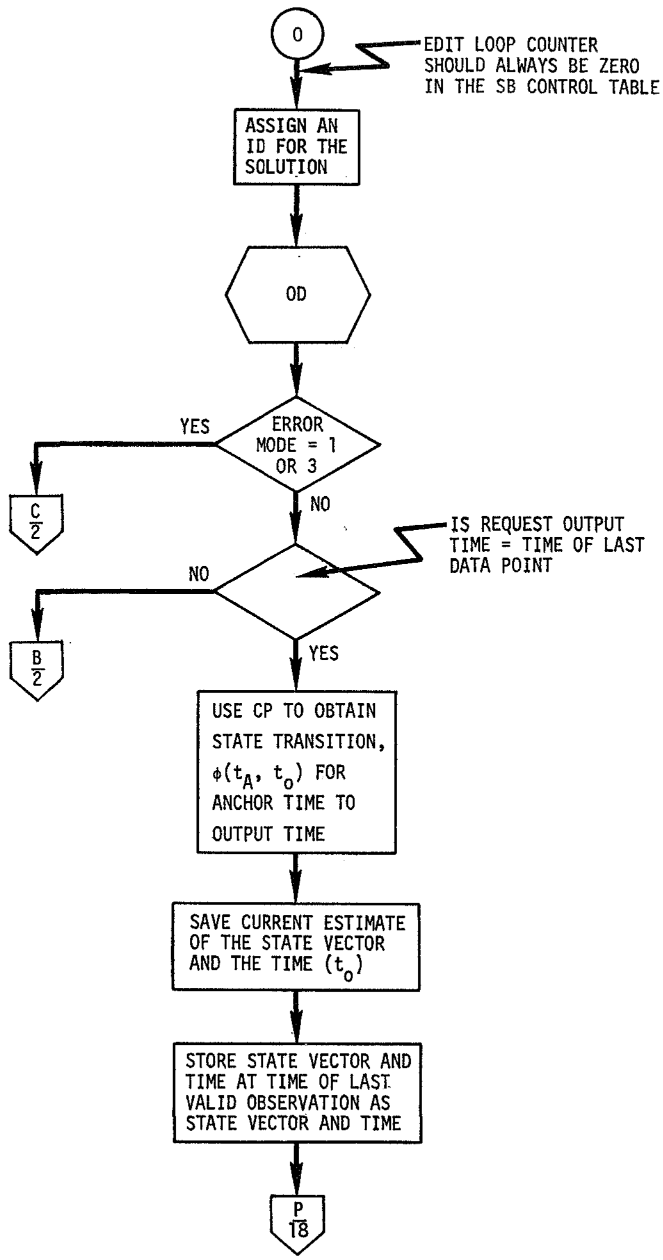
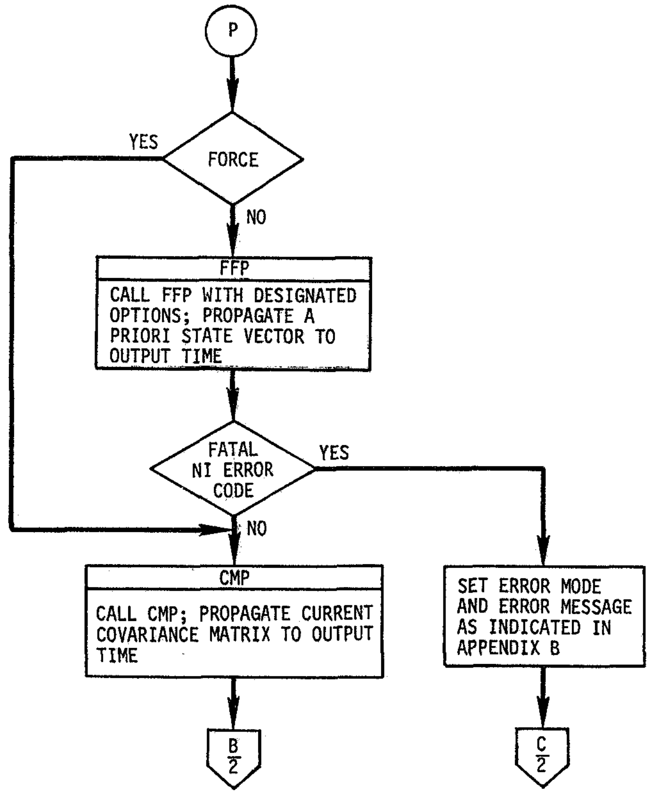


Figure A-1.- Continued.



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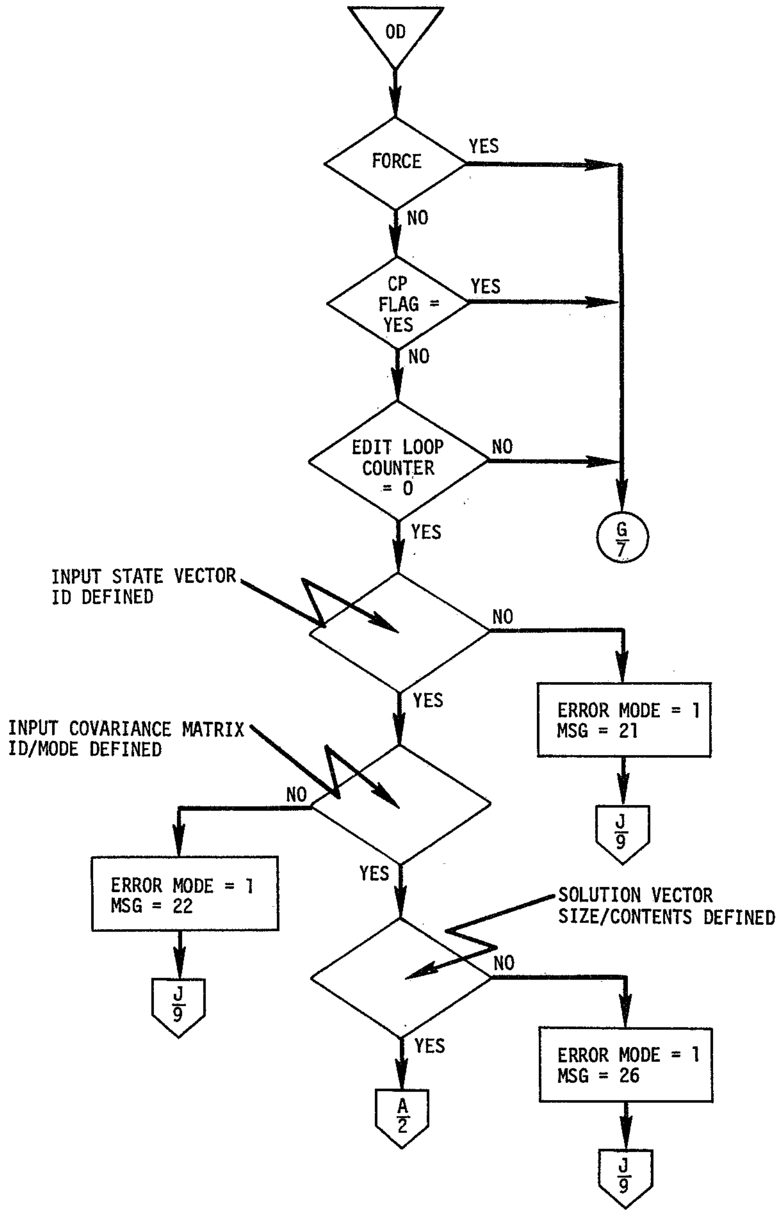

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Figure A-2.- Flow diagram for the orbit determination (OD) process.

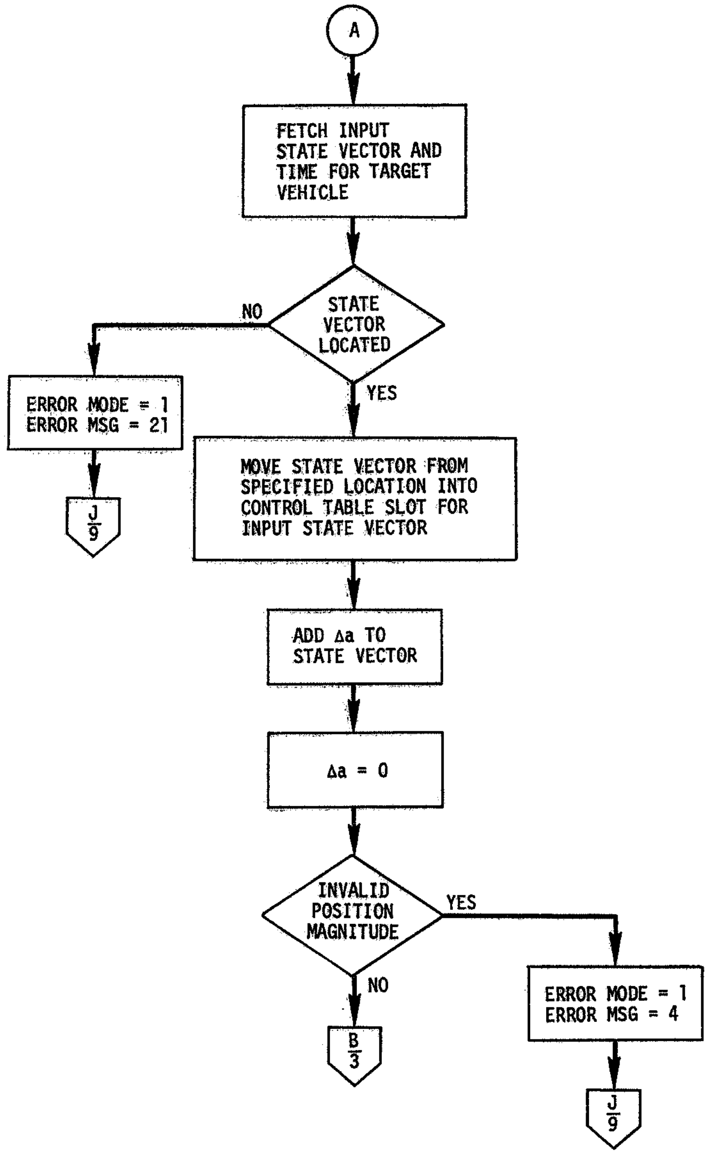

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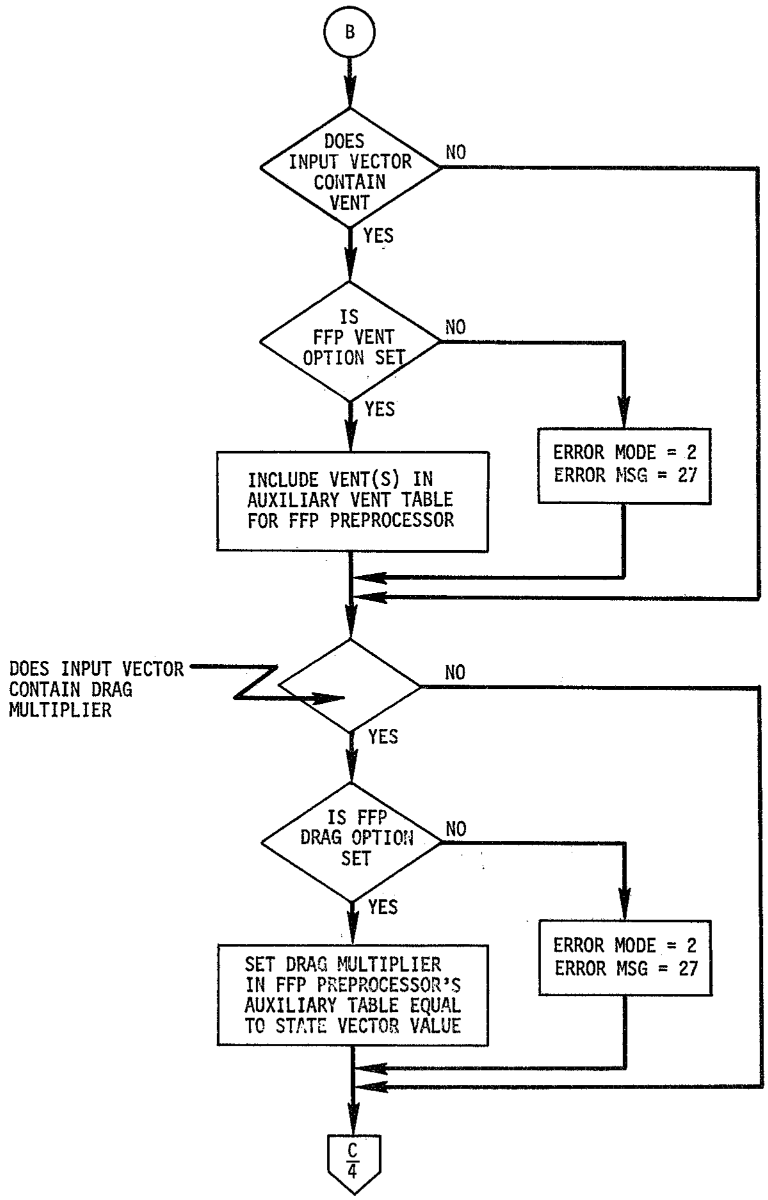
Figure A-2.- Continued.



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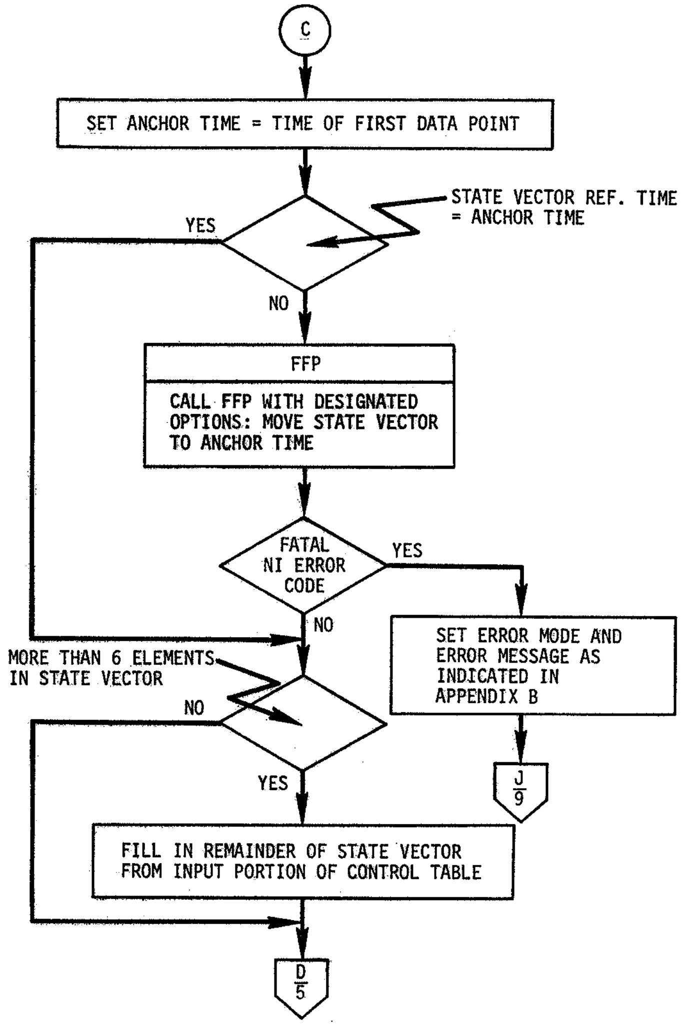

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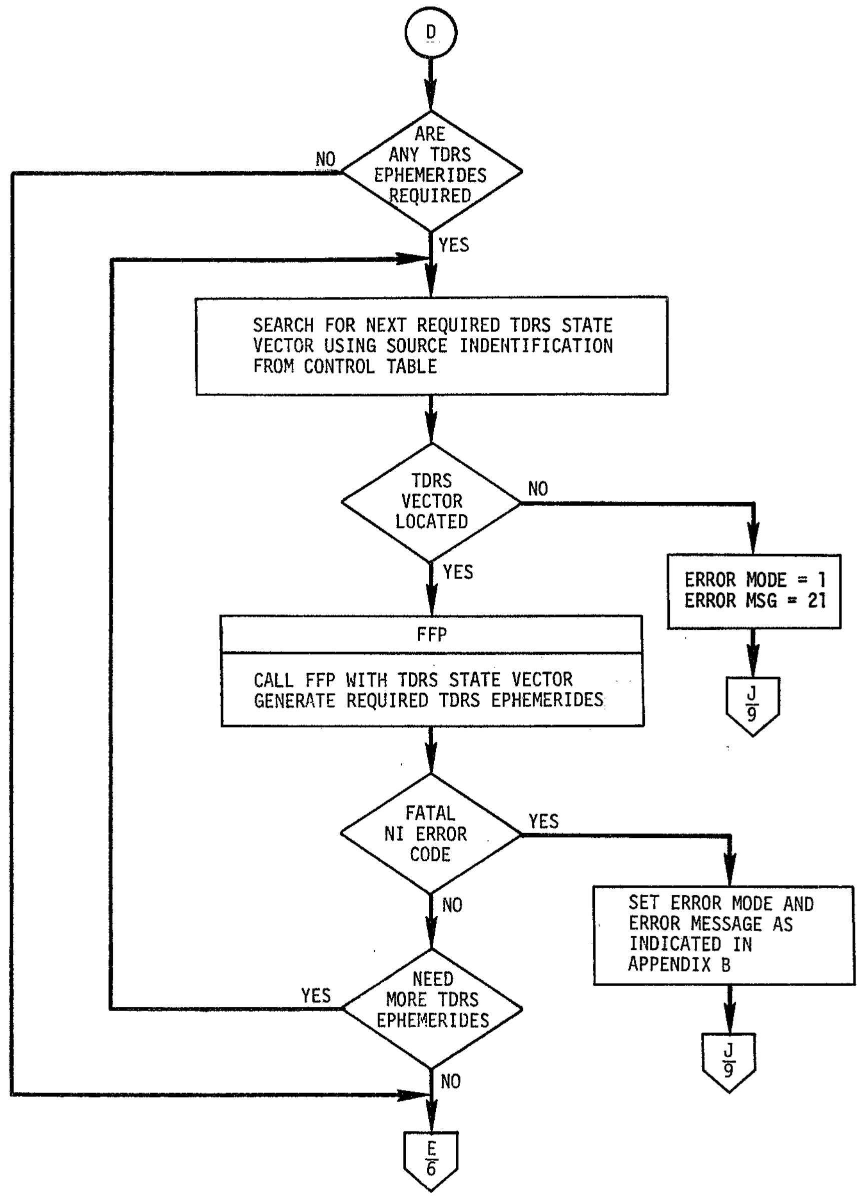
Figure A-2.- Continued.



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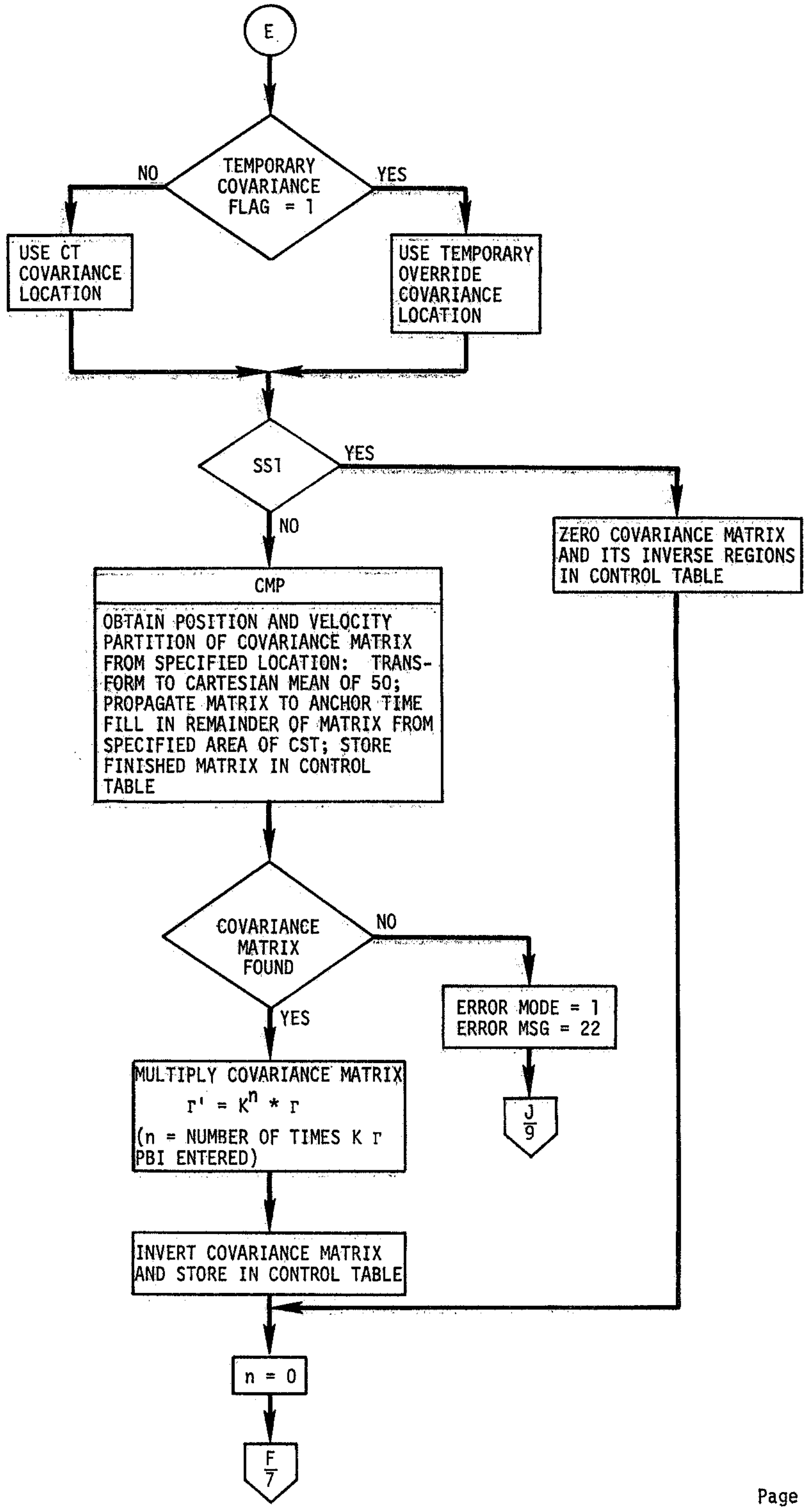

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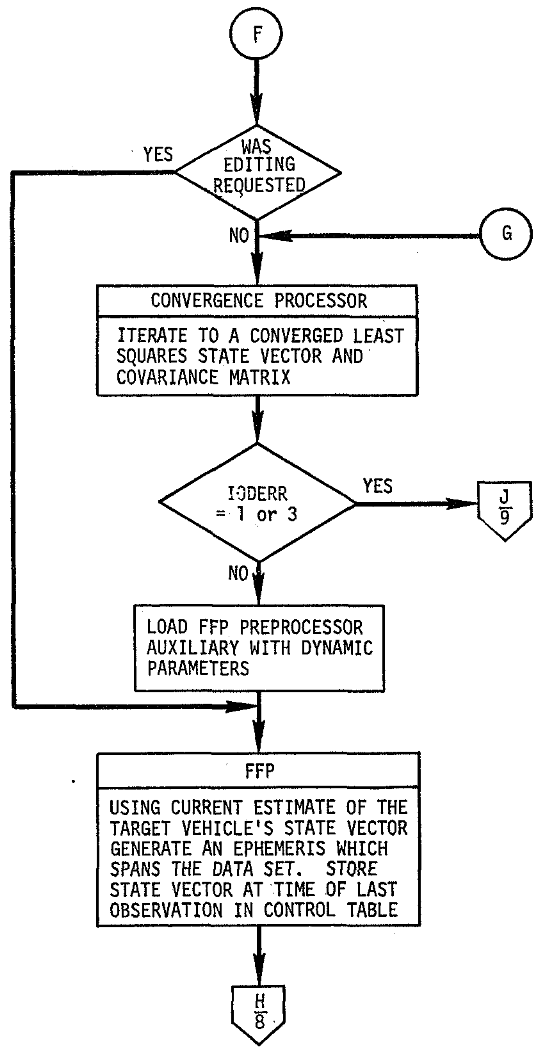

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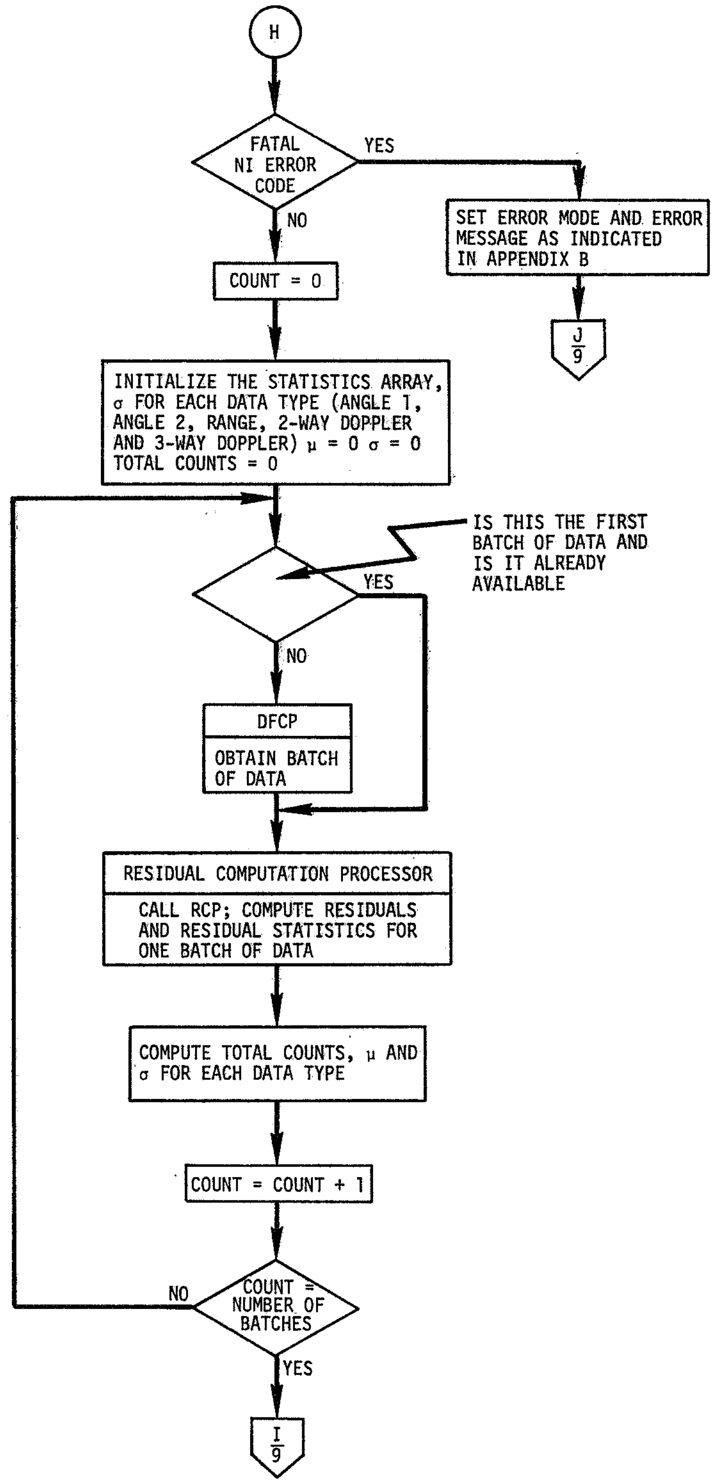

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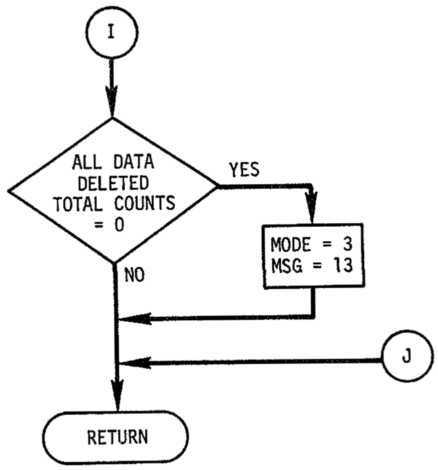

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Figure A-2.- Concluded.

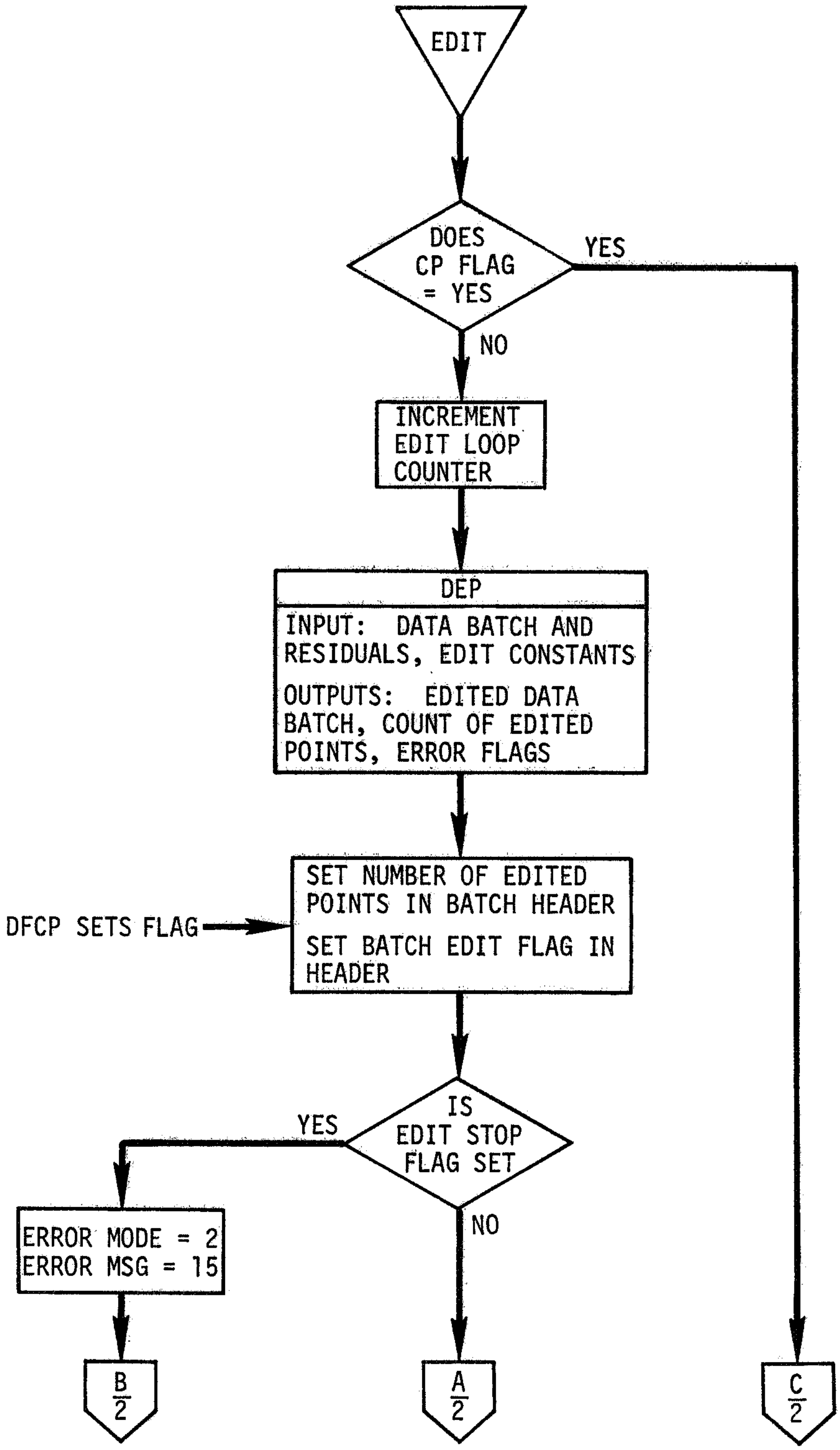

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Figure A-3.- Flow diagram for the EDIT process.

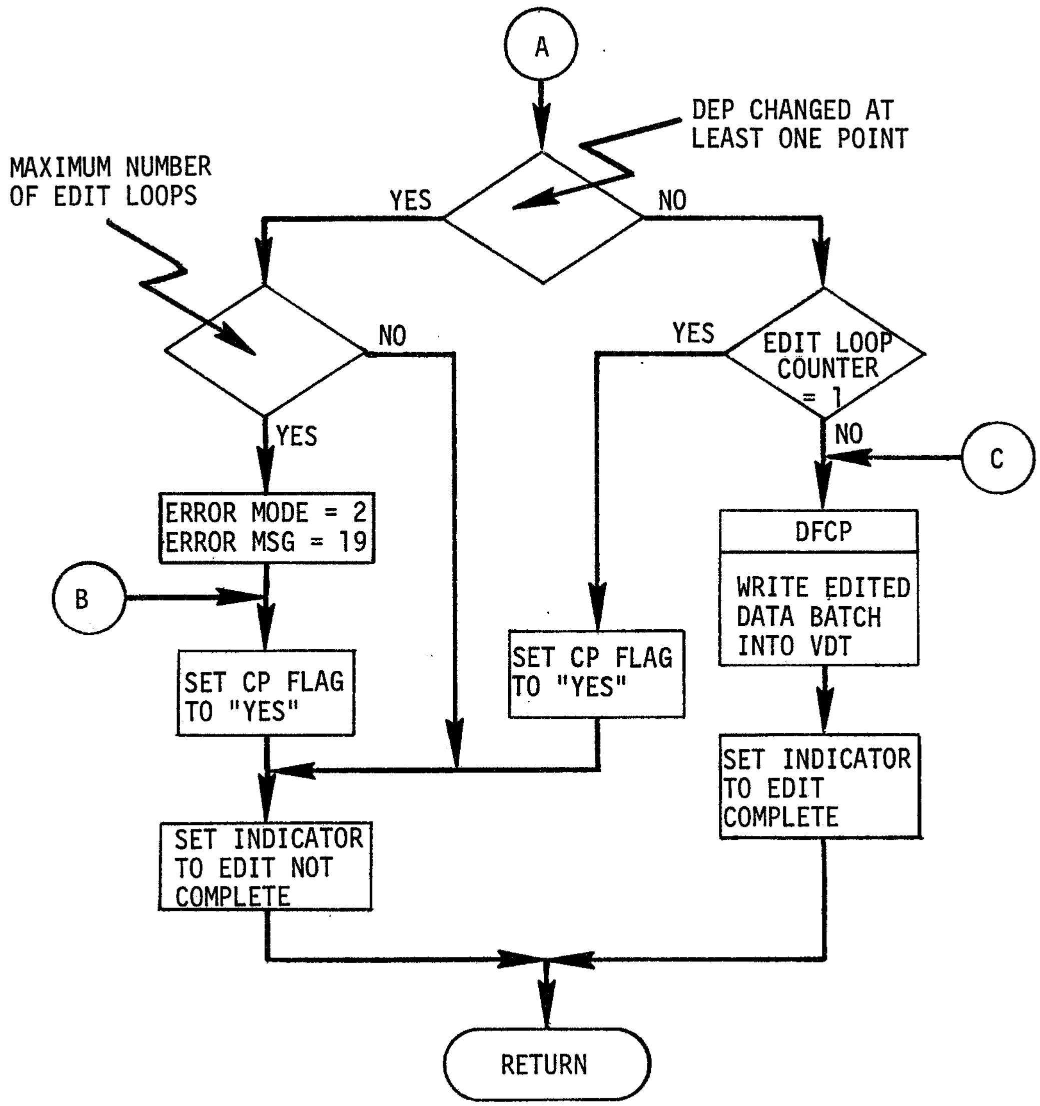

Figure A-3.- Concluded. Page 2 of 2

APPENDIX B

ODE ERROR MESSAGE SUMMARY

APPENDIX B

ODE ERROR MESSAGE SUMMARY

Numerous conditions that may occur within the DCM, CP, ODP, and/or ODE require error messages to alert the user.

a. Error message generation

Error messages shall be generated by the ODE for display only. The error message or an abbreviation thereof shall be stored for display purposes. Each of these unique error messages shall have associated with it, also for display purposes, an error message number in the form of a positive two-digit integer.

b. Error modes for OD output displays

The OD output displays (current BB output, current DCE output, and current SB output) shall be driven in one of four error modes whenever an error condition occurs.

(1) Error mode 1

When an error condition occurs that prevents execution of an OD solution, the related output display shall be driven in error mode 1. All output information shall be blanked. Input data shall be displayed nominally. The user error message indicating the nature of the error condition shall be displayed. The PET and GMT of the last display update shall be driven nominally. The user decision status indicator shall indicate ERROR. The solution ID that would have been assigned to the solution had it been executed shall be displayed.

(2) Error mode 2

When an error condition occurs that does not prevent the execution of a requested OD solution but which indicates that the output may be questionable or invalid, the related output display shall be driven in error mode 2. All input and output information shall be displayed nominally. The user error message indicating the nature of the error condition shall be displayed. The user decision status indicator shall indicate WAITING. The solution ID shall be assigned and displayed nominally.

(3) Error mode 3

When an error condition occurs that does not prevent the execution of a requested OD solution but which indicates that output data are unquestionably invalid and/or unusable, the related output display shall be driven in error mode 3. All output shall be identical to error mode 1 except that the following output data shall be displayed.

(a) Data set count

(aa) Total number of observations

(bb) Number of edited observations

(cc) Number of unedited observations excluded

(dd) Number of accepted observations

(b) Number of iterations

(c) Number of divergent iterations

(4) Error mode 4

When an error condition occurs that prevents the execution of a FORCE, ACCEPT, or REJECT PBI request, the related output display shall be driven in error mode 4. All previous input and output data shall be retained. The user error message indicating the nature of the errors shall be displayed. The PET and GMT of the last display update shall be driven nominally. The user decision status indicator shall indicate ERROR.

The various error messages and their associated error modes are summarized in the following table. References B-1 and B-2 provide more detailed descriptions.

APPENDIX B REFERENCES

B-1 Osburn, R. K., and Wollenhaupt, W. R.: OPS MCC Ground Navigation Program, Level C Orbit Determination Processing, Display and Control Requirements, Introduction, Overview, and Functional Requirements. JSC IN 78-FM-46, Oct. 1978

B-2 IBM Federal Systems Division. Ground Based Space Systems, CCS Trajectory Design Specification. NAS 9-14350, Feb. 1, 1977.

APPENDIX C

INTERFACE TABLES

ODE → CMP INTERFACE TABLE

(Propagation of SB solution covariance to endtime)

ODE parameter[a]	CMP parameter[b]	Unit	Description
$\Lambda(t_0)$	$\Lambda(t_0)$	Internal	SB solution covariance at SB anchor time
$\phi(t_F, t_0)$	$\phi(t_F, t_0)$	Internal	State transition matrix, 6 x (6 + m) where m = number of dynamic parameters in solution vector
$VFLAG_i$ DFLAG $BFLAG_i$	Solution vector content	Flag	Identifies "solve-for" dynamic parameters and biases in solution vector

CMP → ODE INTERFACE TABLE

CMP parameter[b]	ODE parameter[a]	Unit	Description
$\Lambda(t_F)$	$\Lambda(t_F)$	Internal	SB solution covariance propagated to SB endtime, t_F

[a]See section 10.0 of this document.
[b]See section 3.1.1 of volume IX.

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!     ! to  !     !
! ODE !---->! CMP !  INTERFACE TABLE
!_____!     !_____!
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(DC a priori covariance constants)

ODE parameter[a]	CMP parameter[b]	Unit	Description
VID	Link ID	Flag	Identifies vehicle
RCOVID	Covariance ID	Flag	Location of input covariance
ACOVID	Solution parameter ID	Flag	Location in CST (BCOV or SnCOV) where dynamic parameter covariance matrices are stored
$VFLAG_i$ DFLAG $BFLAG_i$	Solution vector content	Flag	Identifies dynamic parameters in solution vector
X_p, t_A	X_A, t_A	Internal	Anchor state (M50) and time
X_{TIG_n} T_{TIG_n}	X_{TIGN} T_{TIGN}	Internal	M50 state and epoch for each maneuver between input time and anchor time

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!     ! to  !     !
! CMP !---->! ODE !  INTERFACE TABLE
!_____!     !_____!
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ODE parameter[b]	CMP parameter[a]	Unit	Description
$\Lambda(t_A)$	$\Lambda(t_A)$	Internal	A priori covariance at DC anchor time, t_A

[a]See section 7.2.2 of this document.
[b]See section 3.1.1 of volume IX.

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!    ! to  !    !
! ODE !--->! CP !  INTERFACE TABLE
!____!     !____!
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ODE parameter[a]	CMP parameter	Unit	Description
--	Link ID		DC link ID
SRF	P_F	Flag	Solution request flag (SRF = 6 means force)
--	DTXCL	Flag	Measurement type exclusion flags (C-band azimuth, C-band elevation, etc.)
$VFLAG_i$ $DFLAG_i$ $BFLAG_i$	SVFLGS	Flag	Identifies dynamic parameters in solution vector
$VSTART_i$	$T_{VNT}(I)$	hr	Vent number i start time
$VSTOP_i$	$S_{VNT}(I)$	hr	Vent number i stop time
GMTEND = t_ℓ	T_{END}	hr	GMT of last valid data point
MINEL	E_D	Internal	Minimum elevation for ground direct
RMNEN	E_R	Internal	Minimum elevation for ground/TDRS
MINCA	h_M	Internal	Minimum RF path alitude vehicle/TDRS
INTEG	INTEG	Flag	Integrator force model option
MAXIT = JMAX	JMAX	Integer	Maximum number of DCM iterations
MAXDV = KMAX	KMAX	Integer	Maximum number of divergent iterations

[a]See section 13.0 of this document.

! ODE ! to ! CP ! INTERFACE TABLE

ODE parameter[a]	CMP parameter	Unit	Description
$\bar{E} = \begin{bmatrix} CR \\ CVEL \\ CVENT \\ CDRAG \\ CBIAS \end{bmatrix}$	$\bar{E}$	Internal	Convergence criteria

[a]See section 13.0 of this document.

ODE to CP INTERFACE TABLE

ODE parameter	CMP parameter	Unit	ODE vol. V, sec.	Description
$\bar{X}_p$	$\bar{X}_p$	Internal	13.0	A priori state vector
$\bar{\Lambda}_p^{-1}$	Λ_p	Internal	13.0	A priori covariance matrix that is KGAMMA degraded and inverted
$\bar{X}_C$	$\bar{X}$	Internal	13.0	Solution vector
$\bar{\Lambda}_C$		Internal	13.0	Solution covariance
J	J	Integer		Iteration count of last call to DCM
K	K	Integer		Divergent iteration count of last call to DCM
$\Delta\bar{S}$	S_j	Internal		Vector of absolute values of changes to a priori vector
$\delta\bar{X}$	$\delta\bar{X}$	Internal		Differential correction
$\delta\bar{X}_p$	$\delta\bar{X}_p$	Internal		Total differential correction on last call to DCM
$\overline{EPH}(I)$	VEPH	Internal	10.0	TDRS ephemerides
Data batch	Data batches		4.0	Batch of data to be processed
Data super-batch	Data batches		4.0	Superbatch of data to processed
n	N	Integer		Number of elements in solution vector
BTIMES	BTIMES	hr		Batch times of each batch

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!‾‾‾‾‾‾! to  !‾‾‾‾!
! ODE  !---->! CP !  INTERFACE TABLE
!______!     !____!
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ODE parameter	CMP parameter	Unit	ODE vol. V, sec.	Description
NB	NB	Integer		Total number of batches
ΔT	ΔT	hr		Length of data arc
SCT	SCT			Station characteristics table

CP $\longrightarrow$ ODE INTERFACE TABLE

CP parameter	ODE parameter[a]	Unit	Description
P_C	P_C	Flag	Divergence error flag
P_{IT}	P_{IT}	Flag	Iteration error flag
P_e	P_e	Flag	Convergence flag
J	J	Integer	Iteration count
K	K	Integer	Divergent iteration count
$\delta\overline{X}$	$\delta\overline{X}$	Internal	Differential correction
$\delta\overline{X}_p$	$\delta\overline{X}_p$	Internal	Total differential correction
$\overline{X}_C$	$\overline{X}$	Internal	Solution vector
Λ_C	$\overline{\Lambda}$	Internal	Solution covariance
S_j	$\Delta\overline{S}$	Internal	Vector of absolute values of changes to a priori vector
$\Phi(t_\ell, t_o)$	$\Phi(t_\ell, t_o)$	Internal	State transition matrix from endtime to start time of data arc
IODERR	Error mode	Flag	Error mode of error in DCM
D	$D = \delta x^T(\Lambda_p{}^{-1}\delta x_p + A^T W\overline{r})$	Internal	Predicted decrease in residual
RTWR	S	Internal	Sum of squares of residuals

[a]See section 10.0 of this document.

! ODE ! to ! DEP ! INTERFACE TABLE

ODE parameter	DEP parameter	Unit	Description
D	D		Limit that sets the size of the discontinuity that can be accepted (D > 1).
DELTA1	DELTA1		User-definable constant greater than 0, which sets the smallest fractional increase between D_{1B} values that will trigger the automatic edit level setting logic.
DELTA2	DELTA2		User-definable constant greater than 0, which sets the smallest fractional increase between D_{2B} values that will trigger the automatic edit level setting logic.
ELIM	ELIM		Limit that sets the fraction of the data that can be edited before the edit stop flag is set (D < ELIM < 1).
G	G		Integer limit that determines how many consecutively edited points can be accepted (G > 1).
DT	DT		Indicates the measurement types contained within the current batch.
K1	K1		User-definable constant greater than 1, which sets the largest overall increase in D_{1B} values relative to their reference that will be accepted before the automatic level setting logic is triggered.
K2	K2		User-definable constant greater than 1, which sets the largest overall increase in D_{2B} values relative to their reference that will be accepted before the automatic edit limit setting logic is triggered.

ODE to DEP INTERFACE TABLE

ODE parameter	DEP parameter	Unit	Description
MIN1	MIN1		User-definable integer constant that sets the lower limit to the number of points for which a D_1 edit will be performed (MIN1 > 2)
MIN2	MIN2		User-definable integer constant that sets the lower limit to the number of points for which a D_2 edit will be performed (MIN2 > 3).
NF	NF		Number of frames in batch.
R_{OB}	R_{OB}	Internal	Residuals for the batch of observation.
RMIN1,RMIN2, RMIN3	RMIN	Internal	Set of user-definable constants, one for each measurement type, that sets a lower bound below which editing will not occur.
RMAX1,RMAX2, RMAX3	RMAX	Internal	Set of user-definable constants, one for each measurement type, that sets an upper bound beyond which pre-editing will always occur.
S1	S1		User-definable limit between 0 and 1.0 which sets the fraction of D_{1B} values that will not be edited by controlling the reference of the automatic edit limit setting logic.
S2	S2		User-definable limit between 0 and 1.0 which sets the fraction of D_{2B} values that will not be edited by controlling the reference of the automatic edit limit logic.

ODE → DEP INTERFACE TABLE

ODE parameter	DEP parameter	Unit	Description
t_R	T_r	hr	Time tags associated with each residual in batch.
P_{ed}	Edit flags	Flag	Edit flags associated with each residual in batch

! DEP ! to → ! ODE ! INTERFACE TABLE

DEP parameter	ODE parameter	Unit	Description
Edit stop flag	Edit stop flag	Flag	Indicates that the editor has encountered a situation calling for user examination
Edit alter flag	Edit alter flag	Flag	Indicates that the current pass through the editor has caused a change in the batch edit status.
Edit flags	P_{ed}	Flags	Indicates which points in batch of observations were edited.
Batch edited flag	Batch edited flag	Flag	Indicates that the batch has been edited.
Number of edited points		--	Indicates the number of points edited for each observation.

! ODE ! to ! DFCP ! INTERFACE TABLE

ODE parameter[a]	DFCP parameter	Unit	Description
t_{INIT}		hr	Initial time
			Batch ID's for Current batch Rechain batch
			Previous solution ID
			ODE mode
			First batch ID
			Last batch ID

[a]See appendix A, figure A-1 for further definition.

DFCP to ODE INTERFACE TABLE

DFCP parameter	ODE parameter[a]	Unit	Description
		--	Batch ID
	t_0	hr	Time of first valid observation
	t_ℓ		Time of last valid observation
	ΔT	hr	Time span of data arc
		Flag	Error flags
			Number of batches
		hr	Start time for each batch
			ID for each batch
			List of Excluded batch ID's Flags indicating reason for exclusion
			TDRS ID's
			Error flags
	Batch		Data batch

[a]See appendix A, figure A-1 for further definition.

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! ODE  !--->! FFP  !  INTERFACE TABLE
!______!    !______!
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ODE parameter	FFP parameter	Unit	ODE vol. V, sec.	Description
t_{OUT}		hr	Appendix A, figure A-1	Output time
t_A		hr	Appendix A, figure A-1	Anchor time
$\overline{X}_p$		Internal	Appendix A, figure A-1	A priori state at anchor time
INTEG		Flag	Appendix A, figures A-1 and A-2	Integration option
		Internal	Appendix A, figure A-2	Reference time of input vector
		Internal	Appendix A, figure A-2	Input state vector
		hr	Appendix A, figure A-2	Anchor time
		Internal	Appendix A, figure A-2	TDRS state vector
		Internal	Appendix A, figure A-2	Current estimate of solution state

FFP → ODE INTERFACE TABLE

FFP parameter	ODE parameter	Unit	ODE vol. V, sec.	Description
	$\bar{X}_p$	Internal	Appendix A, figure A-1	A priori vector at output time
		Internal	Appendix A, figure A-2	A priori vector at anchor time
		Flag	Appendix A, figures A-1 and A-3	Numerical integration errors
			Appendix A, figure A-2	TDRS ephemeris
		Flag	Appendix A, figure A-2	Vehicle ephemeris

ODE to RCP INTERFACE TABLE

ODE parameter[a]	RCP parameter[b]	Unit	Description
$\overline{\text{EPH}}$(I)	$\overline{\text{BEPH}}$(I)	Internal	Ephemerides spanning the batch
$KBIAS_i$		Hz	Doppler biases for solution vector
$BFLAG_i$		Flag	Solve-for bias flags - identifies elements of the solution vector
MINEL	E_d	rad	Minimum elevation for direct tracking
RMNEN	E_r	rad	Minimum TDRS elevation for relay tracking
MINCA	E_h	E.r.	Minimum RF path altitude for TDRS/vehicle
BATCH	BATCH		Batch of data
SCT	SCT		Station characteristics table

[a]See section 4.0 of this document.
[b]See section 3.1 of volume XIII.

RCP to ODE INTERFACE TABLE

RCP parameter	ODE parameter	Unit	RCP vol. XIII, sec.	ODE vol. V, sec.	Description
					Batch ID
t_R	t_R	hr	3.1, 3.2	10.0	Reference time
OB			3.1, 3.2		Measurement indicator 1 = ANG1 = AZ, $X_{N/S}$, $X_{E/W}$ 2 = ANG2 = El, $Y_{N/S}$, $Y_{E/W}$ 3 = Range 4 = Simple Doppler 5 = Complex Doppler
R_{OB}		Internal	3.1		Residual
P_{ed}		Flag	3.1		Edit flag
$P_{E/h}$		Flag	3.1		Elevation angle/relay RF signal path altitude exclusion flag
NTOT			3.2		Total number of valid observations
NED			3.2		Total number of edited observations
NEX			3.2		Number of unedited excluded observations
NACC			3.2		Number of accepted observations
μ	μ	Internal	3.2	6.0	Mean of accepted observations
σ	σ	Internal	3.2	6.0	Standard deviation of accepted observations

RCP to ODE INTERFACE TABLE

RCP parameter	ODE parameter	Unit	RCP vol. XIII, sec.	ODE vol. V, sec.	Description
RMS	RMS	Internal	3.2	6.0	RMS of accepted observations

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